Stelco Tower
The design report

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Stelco Tower
The design report

This book is the design report of the Stelco Tower, a 26-storey office structure located in the heart of the Lloyd D. Jackson Square in downtown Hamilton, Ontario, Canada.

The authors believe that the contents of this book will be of interest to those involved in the development, design, construction and leasing of medium to high-rise office structures.

Contents

stelco

	Page
1: Introduction	
The Lloyd D. Jackson Square	5
Yale Properties	5
Stelco Tower	7
2: Tenant requirements	
Spatial flexibility	9
Modular planning	9
Electrical availability	13
Lighting systems	13
Heating, ventilating, air conditioning	13
Vertical transportation	13
3: Stelco Tower structure	
Preliminary design considerations:	
Selection of structural concept	15
Foundations	15
Structure	15
Effect of HVAC* on exterior wall system	18
Final design, fabrication and erection:	
Concrete core	20
HSS** columns	20
Floor system, composite open web steel joists	20
Connections	32
Costs and floor area	32
4: Fire protection	
Floor-ceiling system	33
Columns	33
Costs	35
5: Exterior wall cladding	
Effect of structure	37
Effect of HVAC system	37
Aesthetics, economics and performance	37
Outer wall	39
Inner wall	39
Installation	41
Costs	41
6: Stelco Tower	
Construction data at a glance	42
7: Conclusions	43

*Heating, Ventilating, Air Conditioning
**Hollow Structural Sections

Figure		Page
1	Original plan for Hamilton Civic Square (1965)	6
2	Hamilton downtown core redevelopment plan (1970)	6
3	Yale Properties plan	7
4	Aerial view of Hamilton's downtown	8
5	Cutaway view of Stelco Tower's lower structure	9
6	Diagram of 5-foot module system	10
7	Electrical availability and lighting system	11
8	Typical floor layout	12
9	Arrangement for Stelco Tower elevator system	13
10	Typical soil conditions of Stelco Tower site	16
11	The Stelco Tower foundation plan	16
12	Stelco Tower column spacing design	17
13	HSS columns at 10-foot centres with horizontal duct system	21
14	Same as fig. 13, with vertical ducting	21
15	HSS columns 4 inches inside the glass line (horizontal ducting)	22
16	Same as fig. 15, with vertical ducting	22
17	Wide flange columns at 25-foot centres with vertical ducting	23
18	HSS columns at 10-foot centres utilizing void as duct supply	23
19	Transfer from concrete to steel columns	24
20	Prefabricated HSS column with spandrel	25
21	Composite open web steel joists	26
22	Stelco Tower joist load deflection curve	27
23	Stelco Tower joist strains	27
24	Joist to column connection	29
25	Joist to core connection	30
26	Floor to core connection	31
27	Fire protection of HSS columns	35
28	Stelcoloy weathering steel curtain-wall	36
29	Cross-section of Stelcoloy weathering steel curtain-wall	38
30	Vertical guide for window washing equipment	40

1: Introduction

The Lloyd D. Jackson Square: Since the mid-fifties, the City of Hamilton has been planning to improve its central business district. This effort was to be combined with one of Canada's most ambitious urban renewal schemes. In 1964, in co-operation with the Federal and Ontario governments, the city retained the consulting firm, Murray V. Jones and Associates Limited, to prepare a detailed proposal for such an urban renewal scheme. Entitled "Civic Square Urban Renewal Scheme", these recommendations were submitted a year later, and were based on a close public-private partnership. Every urban development plan is eventually subjected to the crucial test: Can it be implemented? The consultant's recommendations were adopted in principle by the city and the project's name changed from "Civic Square" to "Lloyd D. Jackson Square", in honour of the former mayor of Hamilton. As originally planned, the Square (bounded by Main, Bay, Merrick and James Streets) consisted of 12 city blocks of varying size having a total area of 43 acres. This area included a portion of the existing commercial-industrial section surrounding the central business district. The majority of the buildings in this area were old, two and three storey structures, punctuated with a number of parking lots.

Murray V. Jones' bold and imaginative scheme for redeveloping a large part of downtown Hamilton includes both public and private participation. Its prime purpose is to rejuvenate both the commercial and cultural activity in the city core. The Lloyd D. Jackson Square faces Hamilton's modern City Hall, and has all the facilities and conveniences of large suburban shopping centres. Moreover, as figure 1 shows, the major new buildings planned in 1965 (theatre-auditorium, department store, library, art gallery, education centre and hotel) combine in making the Lloyd D. Jackson Square the focus for community activities of various kinds. This redevelopment area will be the catalyst to bring people back to the centre of Hamilton, and prevent further deterioration of the downtown business district. The scheme also promises to reshape Hamilton's aesthetic image as a city.

Good planning seldom remains static. Since the original proposal was prepared in 1965, numerous changes and improvements have been carried out, bringing us to the plan which presently exists. Figure 2 shows the 1970 status of the project.

Progress to-date on the entire redevelopment has been encouraging. The education centre was completed in 1967, at a cost of 2½ million dollars. The theatre auditorium is rapidly approaching completion and is scheduled to open in 1973. A 4-million-dollar trade and convention centre is currently in the design stage, with construction scheduled to start in 1973. The planetarium has been eliminated and, at the time of writing, no action has been taken on the library or art gallery.

Yale Properties: The commercial component of the Lloyd D. Jackson Square is basically the heart of the total complex. In addition to all the desirable social features offered by urban renewal, the commercial portion of the scheme was designed to strengthen Hamilton's downtown business district and, as a result, there will be a substantial increase in the amount of tax revenue available from this area. In order to develop the commercial sector, the city requested proposals from private development firms. The successful submission was entered by the Greater Hamilton Developers Limited which is formed by Yale Properties Limited and Standard Life Assurance Company, both of Montreal. Only one thing remained to be solved prior to the official signing: final agreement was dependent upon Yale Properties obtaining a major tenant for the office building. Fortunately, at that time, The Steel Company of Canada, Limited was in the market for new office facilities to accommodate its General Offices. Stelco, anxious to assist in the redevelopment of Hamilton's downtown core, reached agreement with Yale Properties Limited in September 1970. The project's first phase was now viable and ready to start.

The Hamilton redevelopment plan shown in figure 2 was based on the Yale plan (figure 3) prepared by Arthur C. F. Lau Associates, Architects. The Yale plan has a projected cost of 100 million dollars. Construction will proceed in seven phases over a six-year period as follows:

Phase 1
48,000 square foot banking pavilion
26-storey office tower of 392,986 square feet
15,000 square feet of restaurants
110,000 square feet of rentable shopping and retail
2 cinemas with total seating capacity of 1,100 people
290 parking spaces

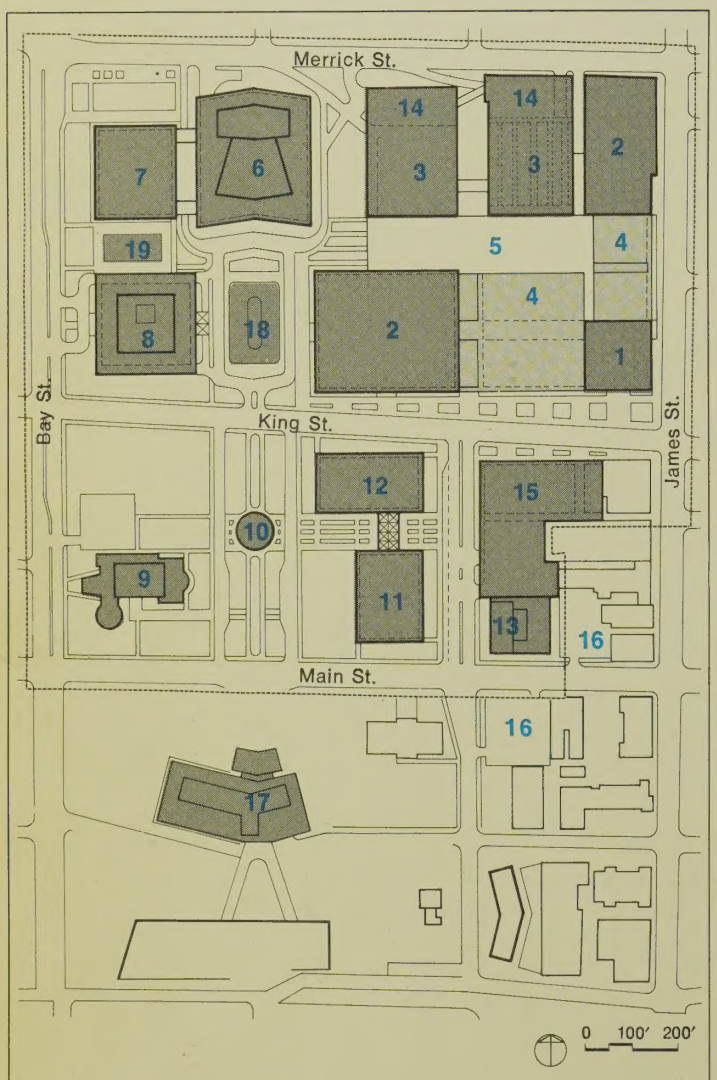


Figure 1 Original plan for Hamilton Civic Square (1965).

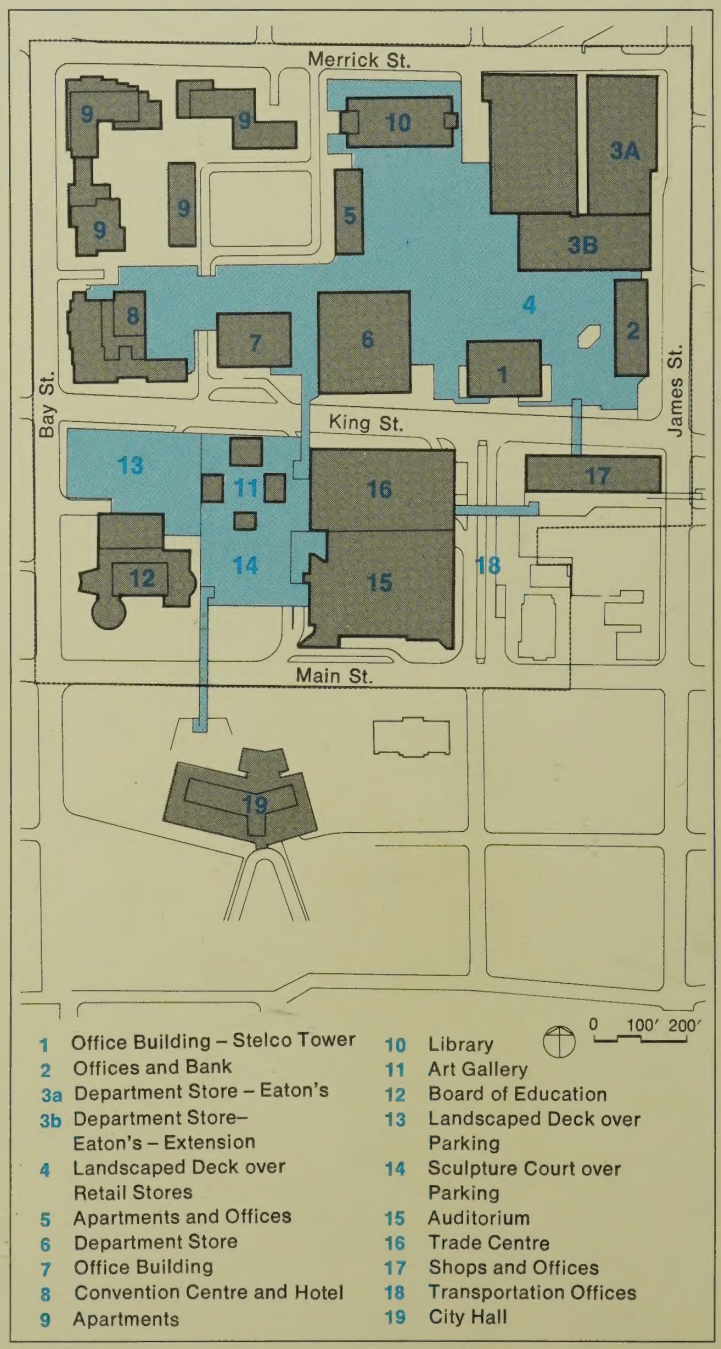


Figure 2 Hamilton downtown core redevelopment plan (1970). The city hall, education centre and theatre-auditorium have been completed or are near completion in locations indicated.

2: Tenant requirements

Tenant requirements play a major role in determining the type and quality of any office building to be constructed. Owners must ensure that they are satisfying the total needs of their tenants by supplying adequate facilities at competitive prices.

Today's office manager is cognizant of the various building features which are required to provide an efficient and comfortable environment. In many cases he will pay a slight premium to ensure that services are of a high standard. This additional expenditure is generally justified by increased office efficiency.

Areas of major concern are:

1 spatial flexibility – large column free areas
2 modular planning – ease of office layout
3 electrical availability – both power and communications
4 lighting system
5 HVAC system*
6 vertical transportation

The following briefly describes how the Stelco Tower has provided the services required to meet the demanding specifications established by Stelco's Office Services Department.

Spatial flexibility: With the increasing trend towards office landscaping, greater emphasis is being placed on large column free areas. This requirement is not only necessary from a spatial flexibility standpoint but also for accoustical reasons. Although a clear span of 60 feet is considered ideal, the 40 feet provided on the Stelco Tower proved satisfactory for this project (figures 5 and 6). Column sizes are also a factor when dealing with spatial flexibility. The smaller the columns, the more space remains for efficient office design.

Modular planning: By establishing a 5-foot module for the structure, standardization of office layout was possible (figure 6). This was desirable not only for areas utilizing office landscaping but also where standard offices were required. Moveable steel partitions were supplied in 2-foot, 6-inch widths by Westeel-Rosco Limited and Stanley-Taymouth Limited. These modular partitions, along with standardized column sizes, kept the number of partition types to a minimum and contributed economically to both the purchase and future relocation of partitions.

*Heating, Ventilating, Air Conditioning

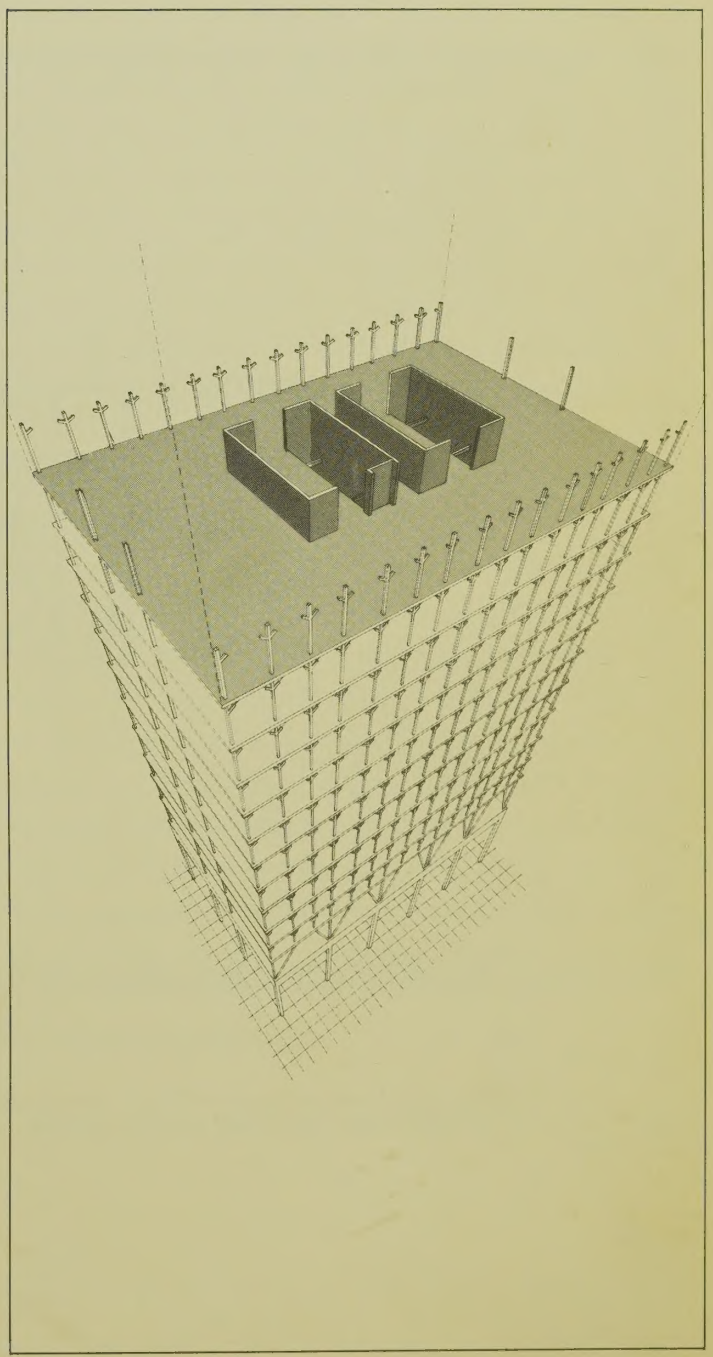


Figure 5 Cutaway view of the Stelco Tower's lower structure. Note the large column-free areas providing maximum spatial flexibility (floor area: 105 by 150 feet).

Figure 6 Lower floor illustrating the 5-foot module system, aiding standardization of office layout throughout the Stelco Tower.

1 Elevator
2 Ducts
3 Ladies' Washroom
4 Men's Washroom
5 Janitor's Closet
6 Electrical Closet
7 Telephone Closet
8 Intercom. Closet
9 Telephone Panel

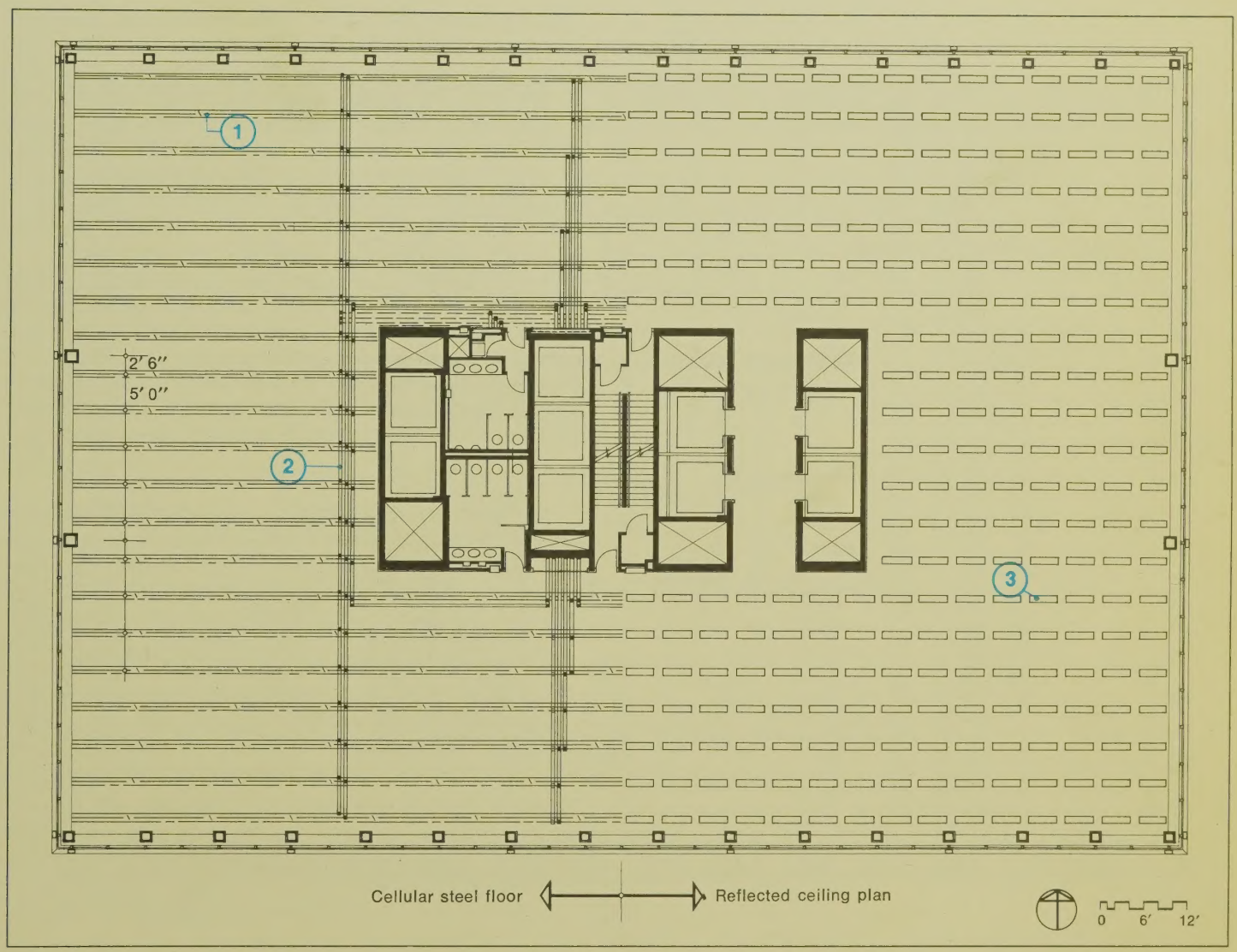


Figure 7 Electrical availability and lighting system.

1 Cells for Communication, Power and Telephone
2 Header Ducts for Communication, Power and Telephone
3 Fluorescent Lighting Fixtures (1′ X 4′)

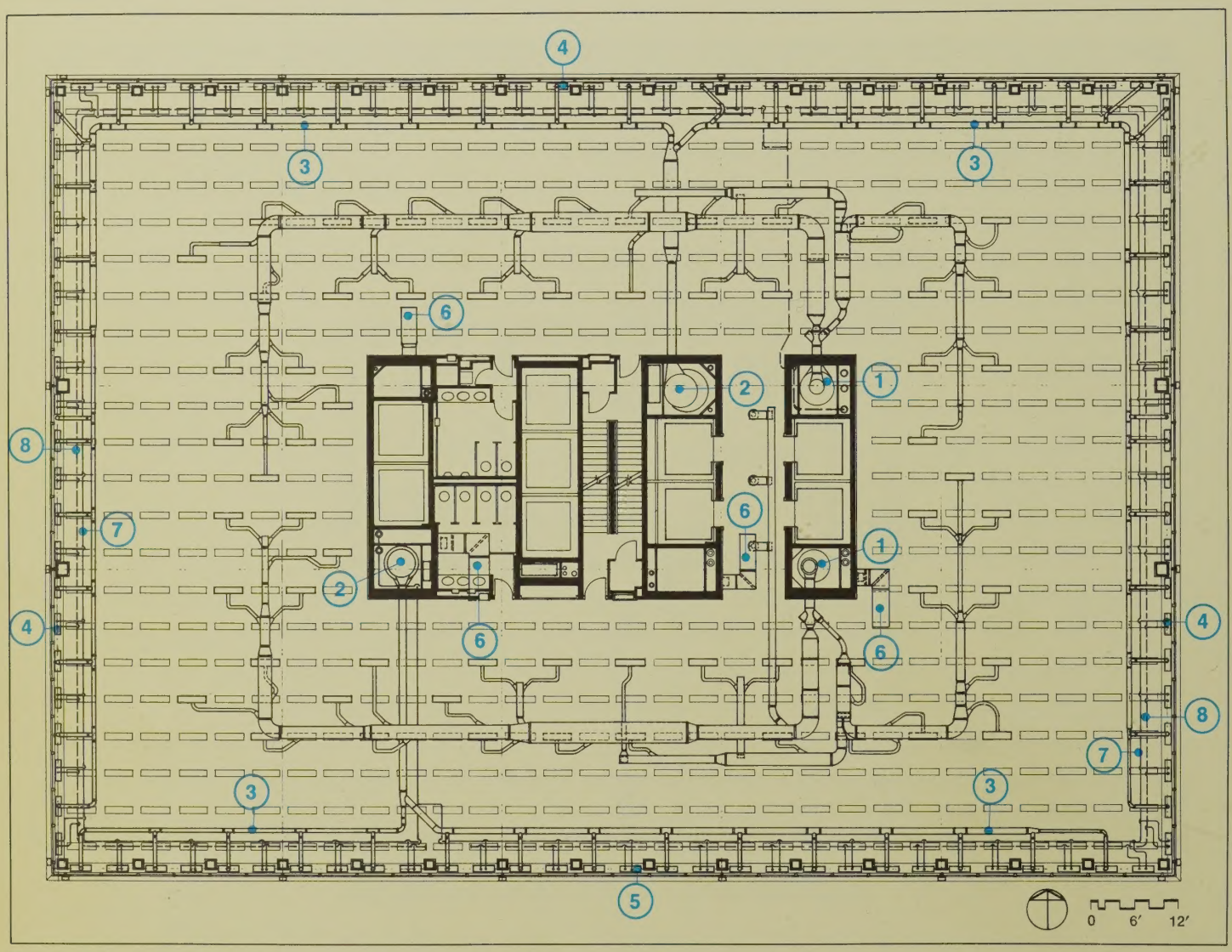


Figure 8 Heating, ventilating, air conditioning (HVAC) layout. Note that ventilating air passes through lighting fixtures.

1 Interior Zone Supply System
2 Perimeter Zone Supply System
3 High Velocity Perimeter Supply Air Duct
4 Induction Units – 50 CFM each
5 Induction Units – 75 CFM each
6 Return Air
7 Water Supply
8 Water Return

Electrical availability: Modern office requirements dictate that adequate space be provided for wiring related to both power and communication services. To insure that present and future needs are met, the Stelco Tower incorporates an underfloor duct system consisting of 3 cells every 5 feet. Two cells will be used for communications (including cathode ray tube equipment) and one cell for electrical power requirements (figure 7).

Lighting systems: A lighting level of 90-100 foot candles at desk level is supplied through recessed fluorescent lighting fixtures. These fixtures which are located on a 5-foot module, are designed to be completely interchangeable with the ceiling panels to provide complete ceiling flexibility. They also act as interior diffusers and return air exit points for the HVAC system.

Heating, ventilating, air conditioning: Heating, ventilating and air conditioning consists of two distinctly separate systems: a low velocity internal loop serving the area closest to the central core, and a high velocity primary air system around the periphery of the building. Induction units are located at 5-foot centres below the window areas (figure 8). The internal loop air is supplied through slots in the lighting fixtures. Varying internal loop air requirements can be satisfied by utilizing the moveable boots which connect to any lighting fixture.

The mechanical and electrical engineers, Keith Associates Limited, have made provision in their design for additional capacity for peak loads which may occur in conference rooms and in special areas where additional heat loads are generated.

Vertical transportation: Two banks of elevators are located in the central core. Four low-rise elevators service the first 12 floors of the tower. Five high speed elevators (operating at speeds up to 800 fpm) service the top 10 floors occupied by Stelco. These high speed elevators provide efficient service for the close to 1000 Stelco employees occupying these upper floors (figure 9).

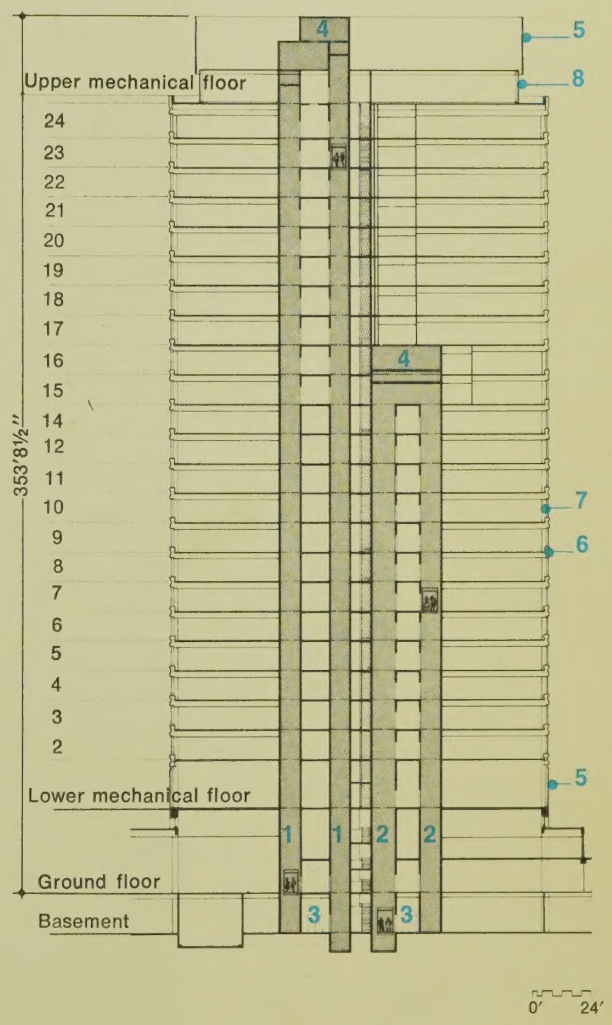
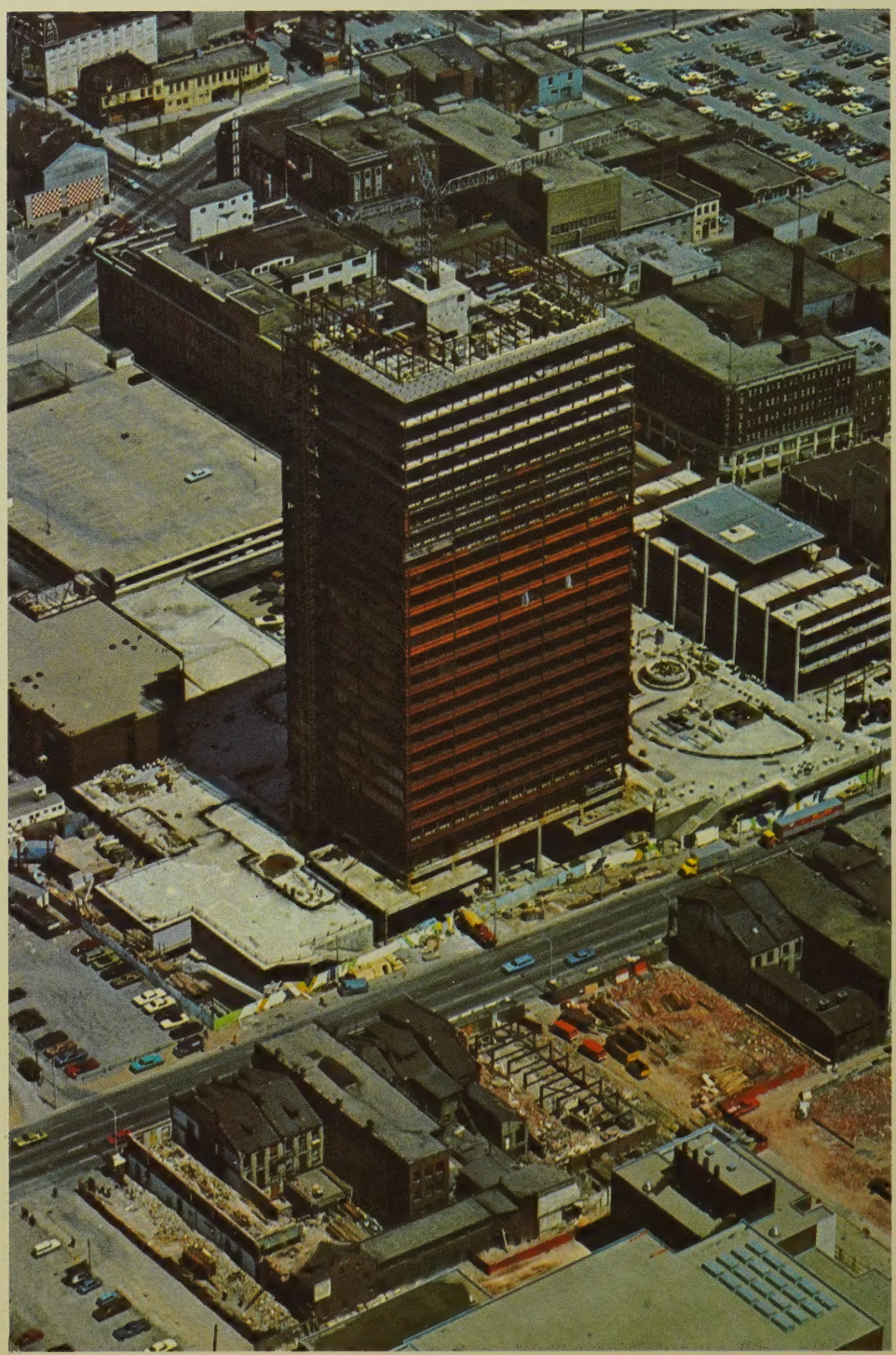


Figure 9 General arrangement for the Stelco Tower elevator system. Four elevators service the first 12 floors and five high-speed units the top 10 floors where Stelco's General offices are located.



Stelco Tower during construction (April 1972).

3: Stelco Tower structure

Preliminary design considerations

Selection of structural concept: As mentioned earlier, Stelco is not the owner of this new office structure, consequently any decision to specify steel products was dependent upon costs being competitive with other structural materials.

Before finalizing the structural concept, the consulting engineers, G. Horvath and Associates, evaluated a number of design alternatives. All were based on a 350-foot high tower with plan dimensions of 105 by 150 feet.

Initially, a concrete frame with 20-foot bays and a two-way floor slab was considered.

As tenant rental agreement requirements became more apparent, the developers realized that 20-foot bays would not provide adequate clear area to permit office landscaping and the necessary spatial flexibility for a modern office. Preliminary designs based on 40-foot clear spans were then undertaken. These designs showed that structural steel would be the most economical framing material.

In evaluating several structural systems, the designers determined that the building would not have sufficient height to make the "tube" method of framing economical (this concept for resisting lateral forces is generally considered economical for buildings in the 45 to 125-storey range).

It was concluded that the most economical approach to meet the requirements of this structure would be a scheme wherein a central core would resist the major portion of the lateral forces due to wind or earthquake (Hamilton is in a R=2 earthquake zone) and carry a portion of the gravity loads. The structural steel framing would assist this core, where necessary, in resisting lateral loads and also carry the gravity loads.

A steel core and a concrete core were compared. On a first cost basis, a concrete core was more economical than a fire-protected steel core (the added cost due to a concrete core's longer construction time was not considered). The concrete core utilized less floor area which was particularly significant to the developer, because it offered more rentable floor space.

Additional advantages of the scheme:
a steel framed office building, braced by a reinforced concrete core and spandrel trusses, is less labour-intensive than a totally reinforced concrete structure,

it results in faster construction (and subsequently earlier occupancy) and

it provides maximum column-free, net floor area at the most economical cost.

Foundations: Soil investigations of the site (figure 10) revealed that the top soil layer generally consists of a loose to medium-dense sandy fill 8 to 10 feet in depth covering a natural sub-soil of a dense to very dense silty sand extending to a depth of 32 feet. Below this point a very stiff to hard silty clay till exists to a depth of approximately 75 feet, below which this silty till becomes very dense. Shale bedrock is encountered at a depth of 141 feet (Elevation 171) and is covered with 7 feet of shattered shale.

Three alternatives were recommended by soil consultants, Racey, McCallum and Bluteau, for the Stelco Tower foundations: conventional spread footings, a structural raft or concrete caissons. Steel pipe piling was ruled out at an early stage due to the extreme depth to bedrock. The possibility of using spread footings or a structural raft was also discarded, because a number of city services (sewers and water mains) were located on the site and any load distributing footing would have to be located below these services. Applying spread footings or raft foundations proved to be too costly, under the circumstances.

Drilled concrete caissons supplied by Franki Canada Limited of Toronto were ultimately chosen for all the column locations and under the concrete core (figure 11). These terminated in the silty clay till sub soil 40 to 45 feet below grade. Exterior sub-surface walls located on the periphery of the plaza area, are supported on standard step footings.

Design loads for the caissons are shown in figure 11. Safe load carrying capacities of these caissons were confirmed by load testing.

Structure: Having decided upon a concrete core and steel framing, the engineers then began establishing column spacings and the type of floor construction to be adopted (figure 12).

Lateral forces were to be resisted primarily by the core. This was easily accomplished in the short direction. But due to numerous openings required for access

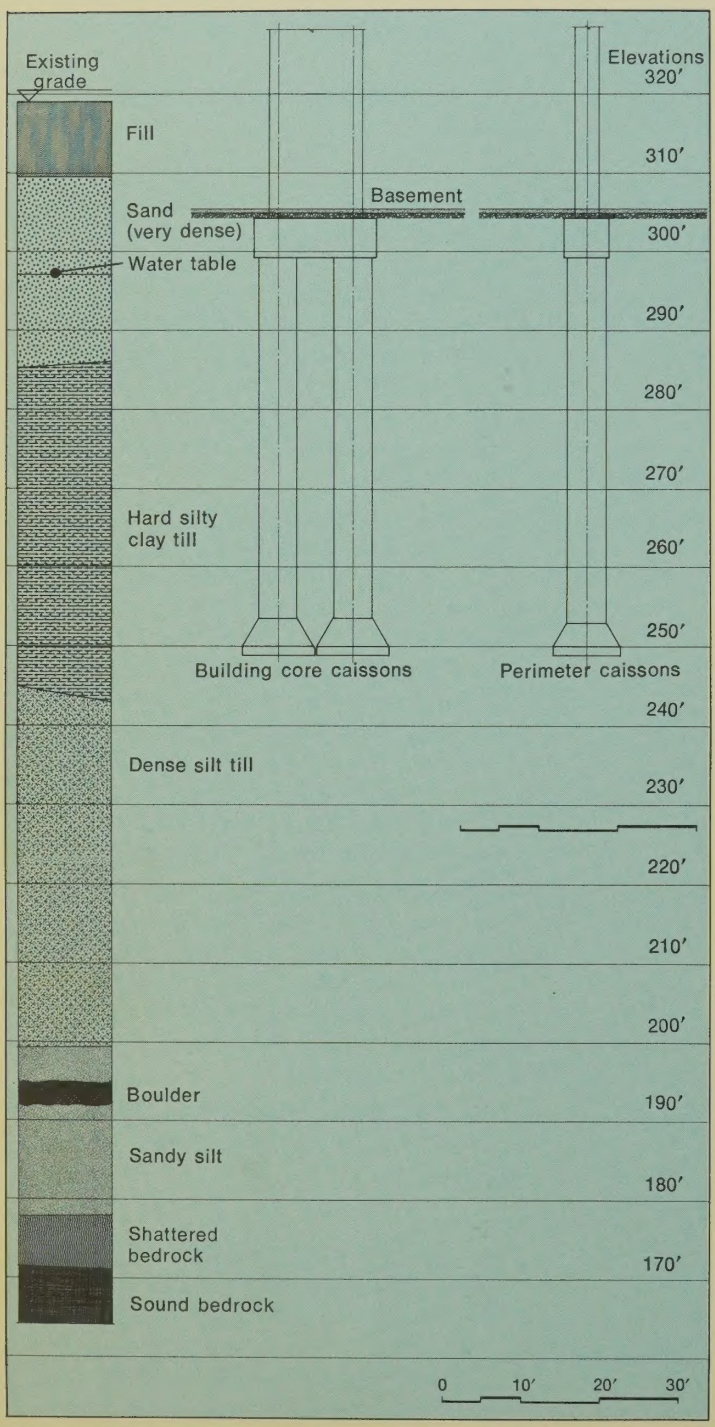


Figure 10 Typical soil conditions on Stelco Tower site.

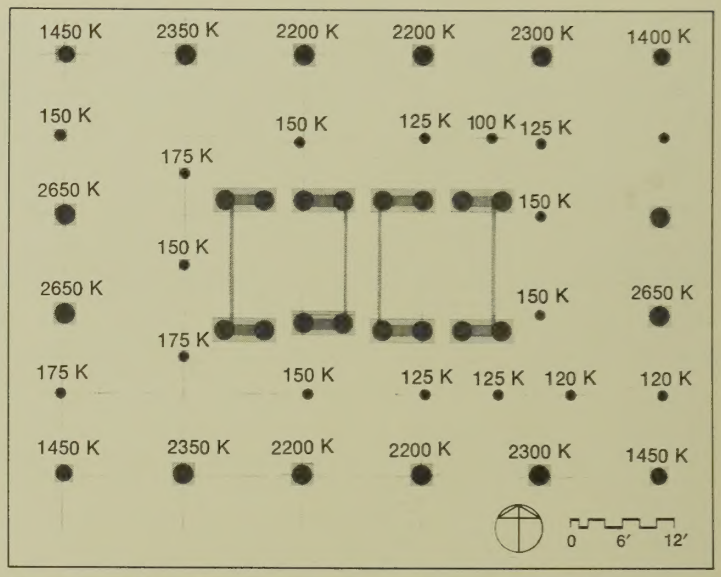


Figure 11 The Stelco Tower foundation plan with caisson load-carrying capacities indicated.

to elevators, washrooms, stairs, etc. along the long side of the core, it was concluded that lateral forces in this direction would have to be resisted by spandrel members. To keep the moments which would be introduced into each column due to lateral forces to a minimum, and to satisfy the requirement of a 5-foot module, the column spacing along the two long sides was selected as 10 feet. This spacing had the additional advantage of making the column sections smaller, thus reducing the amount of penetration by columns into the prime floor space of the offices.

There were several alternatives available to the engineers regarding the type of floor construction to be used. Electrical requirements basically dictated a cellular steel floor. Available floors could tie in with the module by spanning either 5 or 10 feet.

The use of wide flange beam sections to span the 40 feet between core and exterior columns was considered; however, in order to facilitate the mechanical services, holes would have to be made in the webs of these sections. Open web steel floor joists proved to be more economical. It only remained to determine the joist spacing: 5 or 10 feet. The following five com-

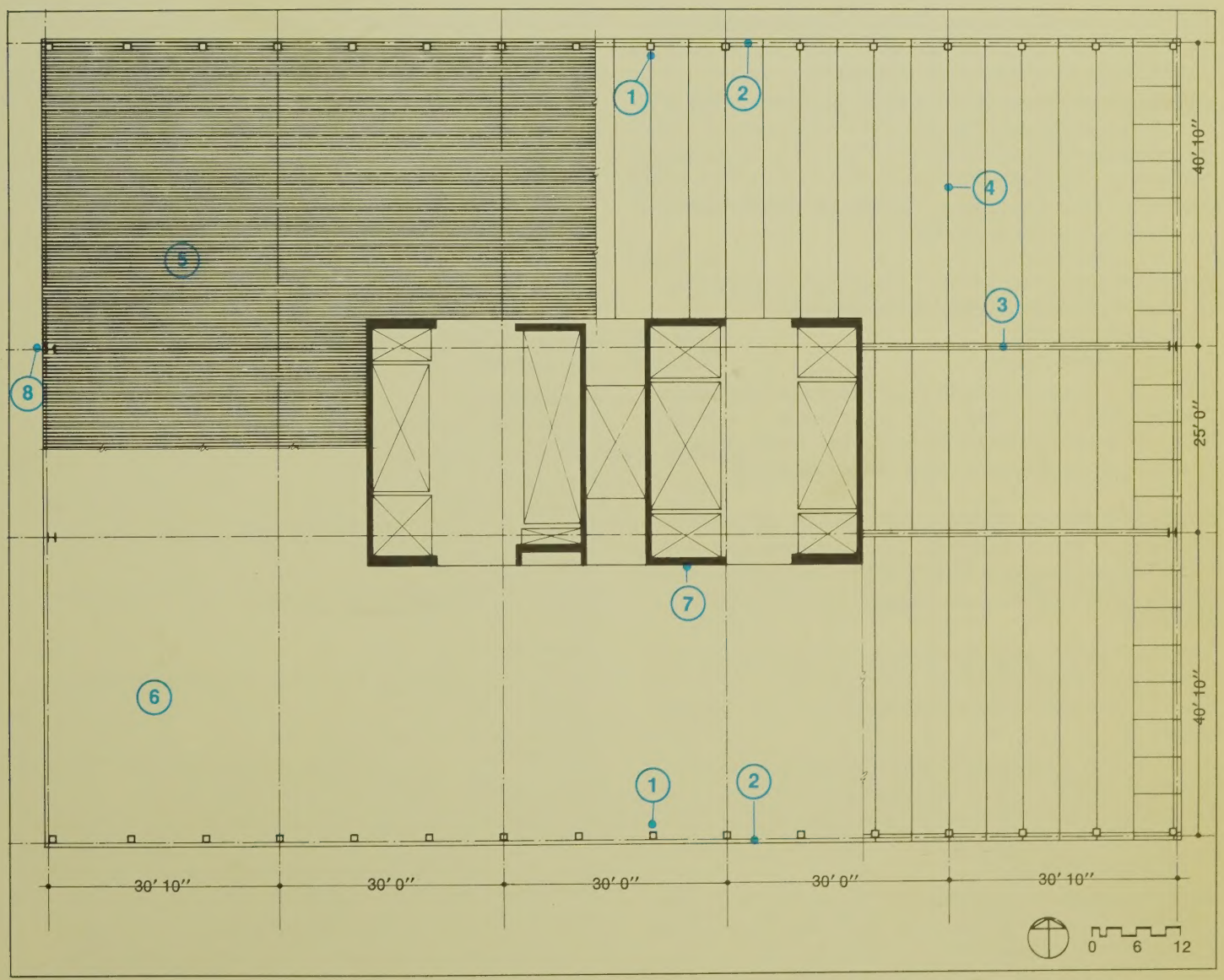


Figure 12 Stelco Tower column spacing and typical lower floor plan. The east bank of elevators terminates at the 14th floor as shown in figure 9.

1 HSS Column
2 Spandrel Girder
3 W.F. Beam
4 Composite Open Web Steel Joist
5 1½" Cellular Steel Floor
6 Concrete Slab
7 Concrete Core Wall
8 W.F. Column

parisons were undertaken (these 1970 prices include the cost of the concrete topping as well as the general contractor's overhead and expenses):

(i) Open web steel joists, 5-feet centre to centre, 1½-inch cellular steel floor:
standard joists: $2.34 psf
composite joists: $2.24 psf

(ii) Open web steel joists, 10-feet centre to centre, 3-inch cellular steel floor:
standard joists: $2.46 psf

(iii) Open web steel joists, 10-feet centre to centre, 1½-inch cellular steel floor (shored):
standard joists: $2.37 psf
composite joists: $2.28 psf

Although the composite joist at 5-foot centres alternative appeared to be the most economical, it was decided to request tenders on both the composite and non-composite joist schemes (5-foot spacing).

Effect of HVAC on exterior wall system: Of prime importance in the comparison between steel and concrete structures is the effect of the heating, ventilating and air conditioning systems on the total cost of the structure.

The mechanical engineers chose a high pressure/low pressure induction system. However, there were two choices for the location of the primary air feeder ducts:

(i) a vertical riser system where the primary-air ducts are located along the periphery columns or
(ii) a horizontal system where the ducts are located in the ceiling plenum and are fed by risers located in the central core.

With a reinforced concrete structure, a vertical riser system for the HVAC services is commonly used, because the risers can pass through holes in the floor slab on the interior side of the periphery columns. With structural steel, however, floor framing members dictate that the vertical risers be located on the outside face of the column as illustrated in figures 14, 16 and 17. This arrangement results in extremely large finished columns or expensive curtain-wall detail. A horizontal system, with the ducts in the ceiling plenum, is more suitable for application in steel structures.

The developer expressed concern that a horizontal duct system might entail a cost premium which had not been included in his original estimates. To evaluate the two systems, the firms of Gordon D. Pattison and Associates and Edward Thornley and Associates were commissioned to conduct a study taking into account the cost of the duct work, its location and its effect on other building components (for example, exterior cladding and fire protection).

This study consisted of six alternatives:

Alternative 1
Hollow structural section (HSS) columns at 10-foot centres projecting outside of the glass line of the exterior wall, with a horizontal duct system supplied from the central core for each floor (figure 13).

Alternative 2
Similar to Alternative 1 but utilizing a vertical riser system (figure 14).

Alternative 3
Columns located approximately 4 inches inside the glassline with a horizontal ducting system (figure 15).

Alternative 4
Similar to alternative 3 with a vertical supply system (figure 16).

Alternative 5
Wide flange columns at 25-foot centres with a vertical supply system (figure 17).

Alternative 6
HSS columns at 10-foot centres and utilizing the void in the column as the duct supply (figure 18).

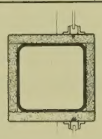
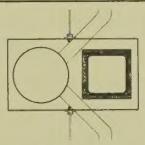
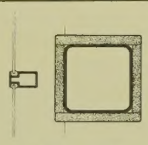
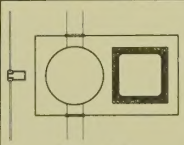
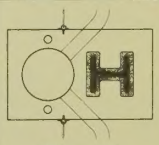
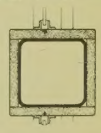
An estimated cost for each system including windows, mullions, fire protection, column covers and duct work was compiled. The estimated cost for each of these alternatives as a function of the gross floor area of one floor (16,129 square feet) are shown in Table 1.

A quick review of the various costs per square foot (Table 1) indicated that the initial concern of a horizontal duct system being more costly than the vertical system was ill founded.

In a further evaluation, conducted by the architect Arthur Lau, alternatives 2, 4 and 5 were ruled out due to the relatively large size columns. The riser ducts running along the column outside faces took up too much space. Loss of floor area resulting from these design alternatives as well as factors affecting spatial flexibility, were objectionable (see comment on Spatial

flexibility, page 9). Alternative 6, while presenting a feasible solution for office structures of less height, did not provide sufficient duct capacity (cross-sectional area of the HSS void) for HVAC requirements in a 26-storey building. Therefore, the decision as to which system to select narrowed down to a choice between alternatives 1 and 3. The architect chose alternative 3 based on past experience, because it offered an uninterrupted wall system and column covers or other projections were not required. He felt that the simplicity of this design alternative would eliminate water tightness difficulties as well as proving more economical, in the final analysis, than alternative 1. Other cost comparisons also indicated that this system would be competitive when compared with concrete and aluminum systems.

Table 1 Estimated costs for alternative HVAC and wall systems*

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
	 (Fig. 13)	 (Fig. 14)	 (Fig. 15)	 (Fig. 16)	 (Fig. 17)	 (Fig. 18)
Column type	HSS	HSS	HSS	HSS	W	HSS
Duct type	Horizontal	Vertical	Horizontal	Vertical	Vertical	Vertical
Column location	Outside glass	Partially outside glass	Inside glass	Inside glass	Partially outside glass	Partially outside glass
1 Windows, etc.	$26,633	$26,633	$28,141	$28,141	$25,243	$26,298
2 Fireproofing	1,858	1,858	1,858	1,858	1,159	2,247
3 Column covering	764	764**	728	728**	2,689	867
4 Void required for ducts	—	***	—	***	****	—
5 Duct work	2,479	2,279	2,479	2,279	2,482	1,131
6 Total cost	$31,734	$31,534**	$33,206	$33,006**	$31,573	$30,543
7 Cost per square foot	$1.97	$1.96**	$2.06	$2.05**	$1.96	$1.90

Notes:

*Prepared by Gordon D. Pattison and Associates and Edward Thornley and Associates.
**No adjustments made for additional space required for ducts.
***No figures available.
****This cost included with column covering.

Stelco Tower structure

Final design, fabrication and erection

Concrete core: The core was designed to stand independently and did not require support from the structural steel frame. Thus core construction could proceed prior to structural steel erection. Due to the intricate configuration of the core (with the great number of openings required) slip forming was considered inadvisable, and the gang forming approach was used.

The concrete core progressed at about one floor every six working days, while the structural steel easily progressed at about two floors every six working days.

Core construction safety regulations dictated that one crew could not work above another without proper protection. This, and the fact that crane time was at a premium, led the contractors to intersperse the pouring of the concrete core with the erection of structural steel. As a result, the core was poured at night and structural steel erected during the daylight hours. Neglecting minor stoppages due to outside factors, these operations proceeded at a fast rate and the method proved most satisfactory.

The lower mechanical floor serves as a transition level for the structural steel columns which are located at 10-foot centres, and the lower reinforced concrete columns at 30-foot centres (figure 19).

Columns: The Stelco Tower represents the first major use of Stelco's hollow structural section (HSS) columns in high rise office construction. The closely spaced columns along the two longitudinal walls (north and south walls in figure 12) vary in size from HSS – 12 x 12 x .450-inch on the 8th floor to HSS – 6 x 6 x .250-inch on the top floor. On the 6th and 7th floors, the designers elected to place two ⅜ x 10-inch flange plates on 12 x 12 x .450-inch HSS sections to provide the necessary capacity. Wide flange sections were utilized up to the 6th floor, where column loads were considerably higher than the capacity of the HSS range.

HSS was chosen whenever possible because of its high ratio of radius of gyration to unit weight, which results in maximum utilization of structural steel in compression. HSS also provides flat, accessible surfaces in both the longitudinal and transverse directions for spandrel and joist connection details. The result: significant savings in column steel through the use of HSS.

Columns were fabricated in Frankel Structural Steel's shop with one half of each spandrel truss welded to each side to form a "tree" section (figure 20). The angles and tees of the spandrels are welded to short wide flange sections which transfer stresses into the stiffer corners of the HSS columns. Simple angle seats and plate connections, welded to the face of the column (figure 20), provide the link between column and joist. Standard end cap plates are fitted at the column splice points. This type of splice connection permits a reduction in outer dimension of the HSS columns as the load decreases.

Floor system: Composite open web steel joists provide one of the more interesting aspects of this project (figure 21). They are incorporated in the floor system of the Stelco Tower and are used in combination with the 1½-inch cellular steel floor and concrete slab. A study conducted during the project's early stages indicated that composite joists are more economical than conventional, non-composite types for spans of approximately 37 feet and longer. Two additional reasons for considering the application of composite open web steel joists became apparent to the designers: composite joists result in a superior structure because they provide stiffer floors with less deflection; and this method offers added assistance in transferring lateral wind forces to the core. After a discussion with the structural engineers, G. Horvath and Associates, it was decided to develop and test a composite open web joist for this project.

An economic study of three alternative floor systems resulted in the final selection of composite joists on 5-foot centres using 1½-inch cellular steel floor and a concrete floor slab. The designers determined that it would be more economical to run all joists in the same direction, thus allowing the cellular steel floor also to span in one direction.

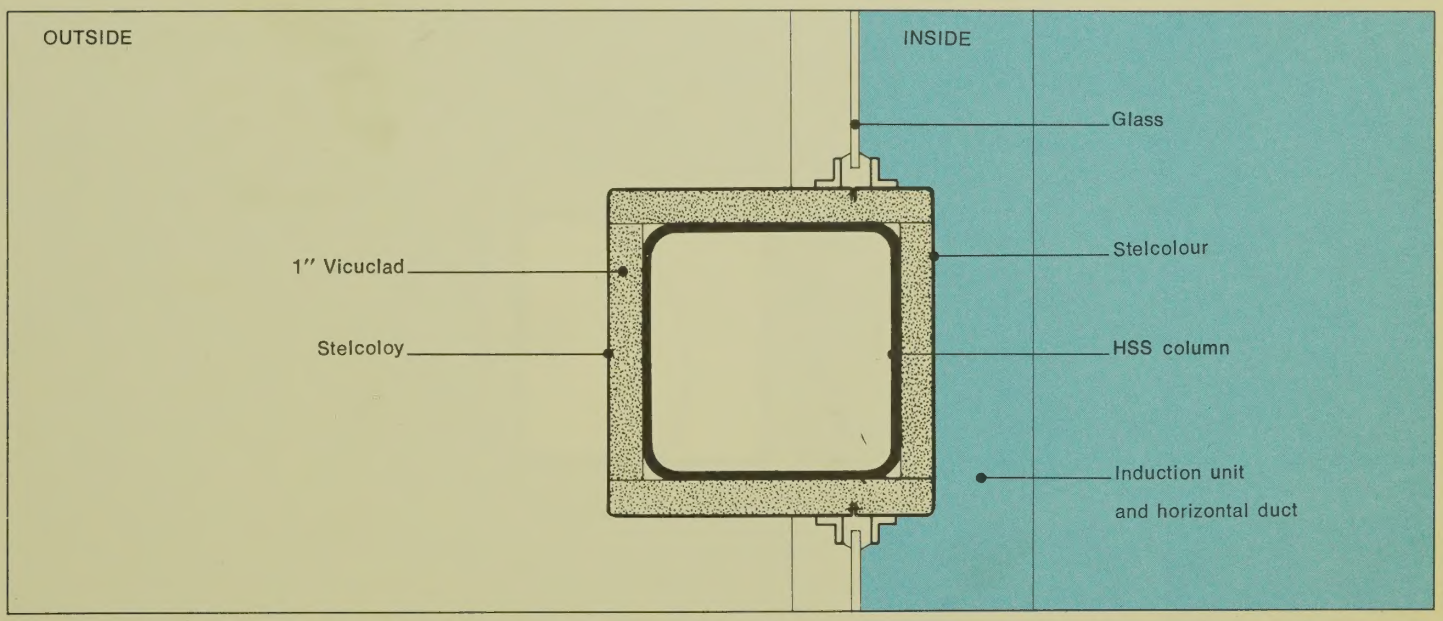


Figure 13 HSS columns at 10-foot centres projecting outside of the glass line of the exterior wall, with a horizontal duct system supplied from the central core for each floor.

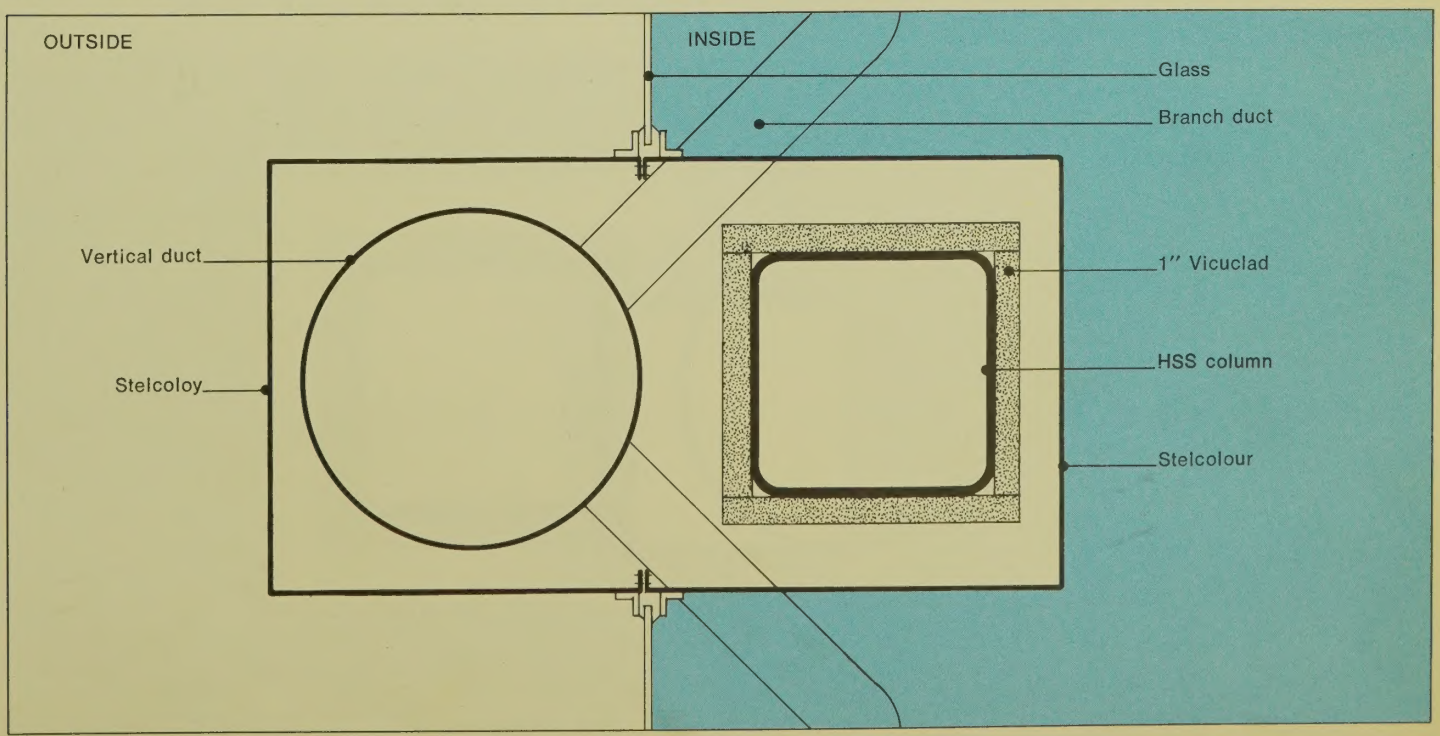


Figure 14 Similar system as figure 13 but utilizing a vertical riser system.

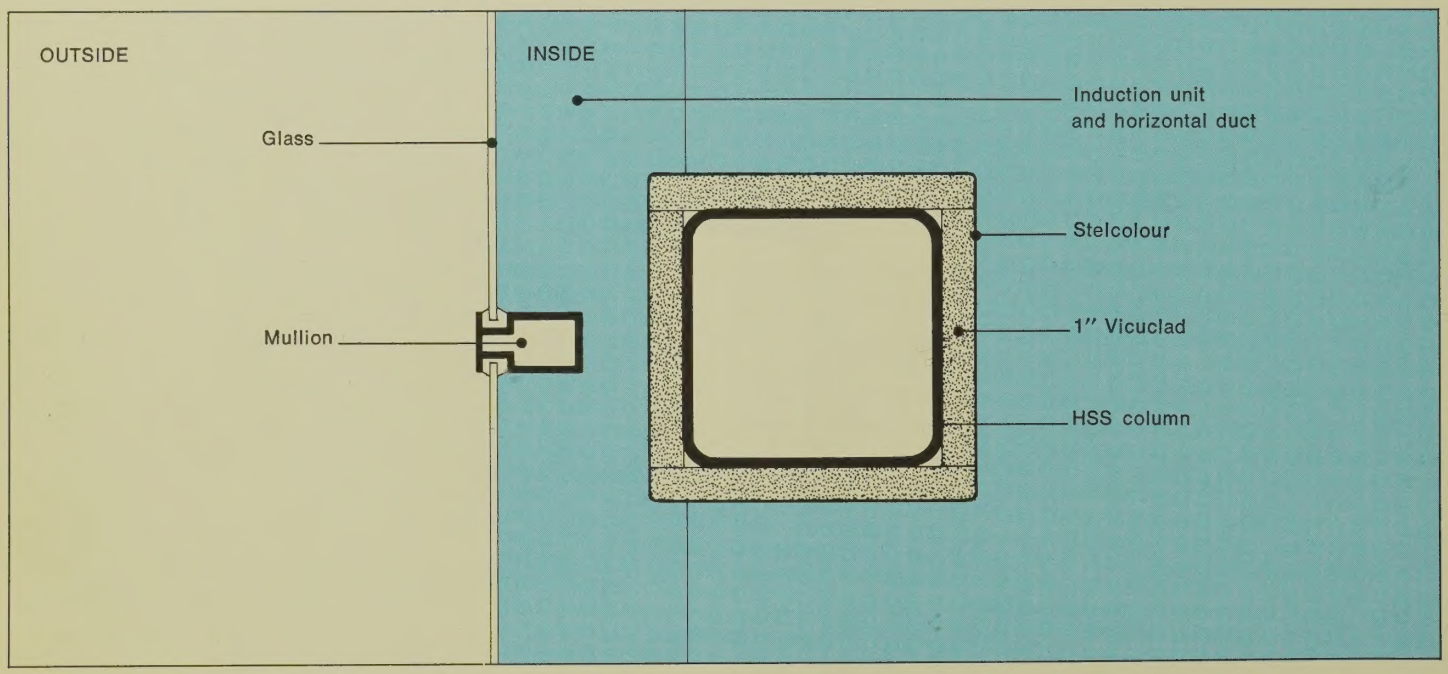


Figure 15 Columns located approximately 4 inches inside the glass line with a horizontal ducting system.

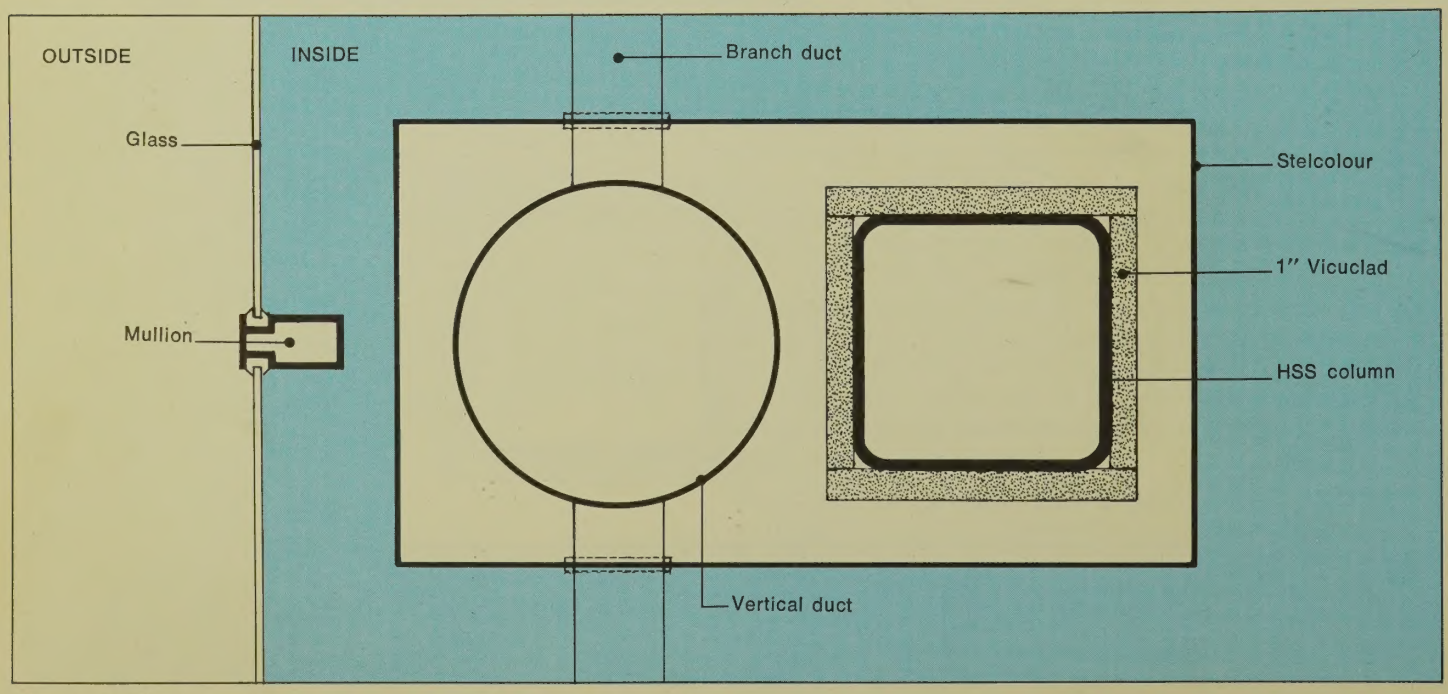


Figure 16 Similar system as figure 15 with a vertical supply system.

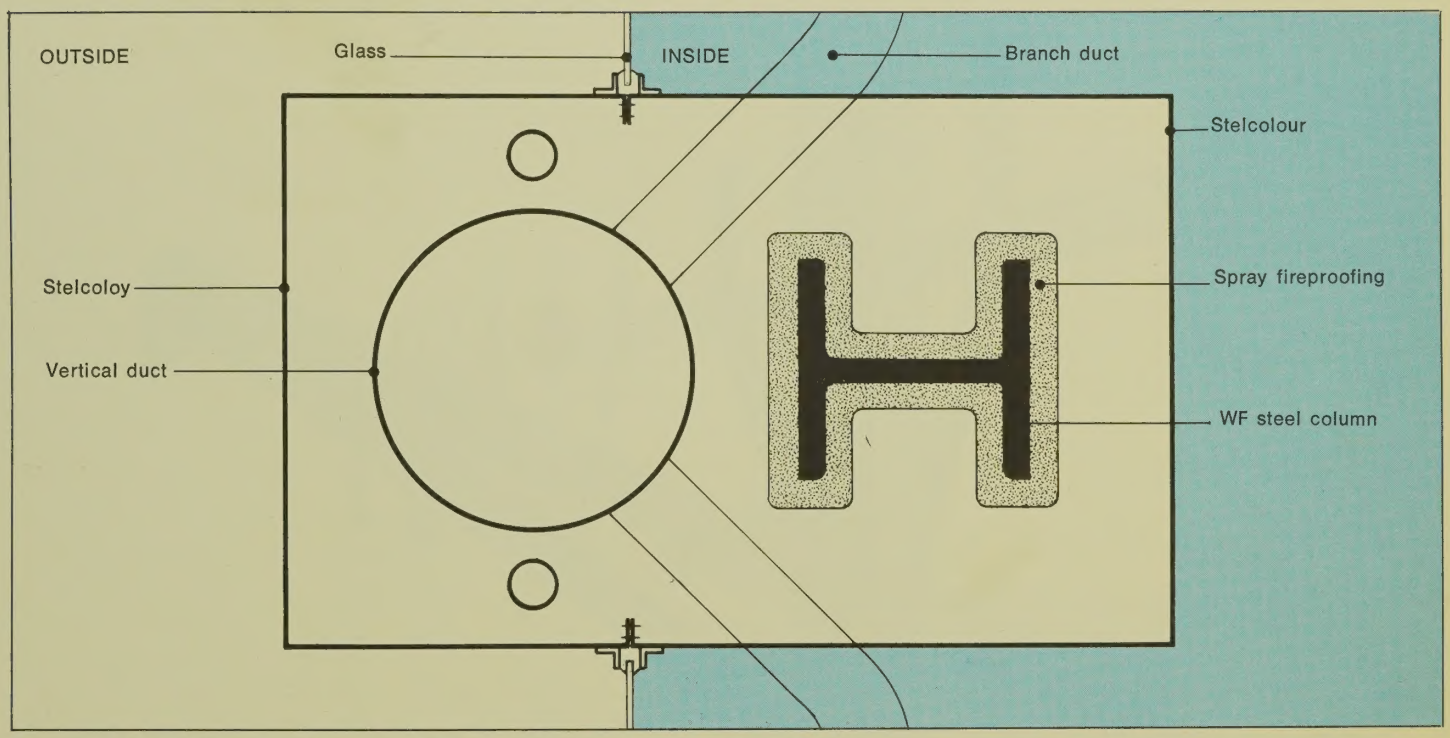


Figure 17 Wide flange columns at 25-foot centres with vertical supply.

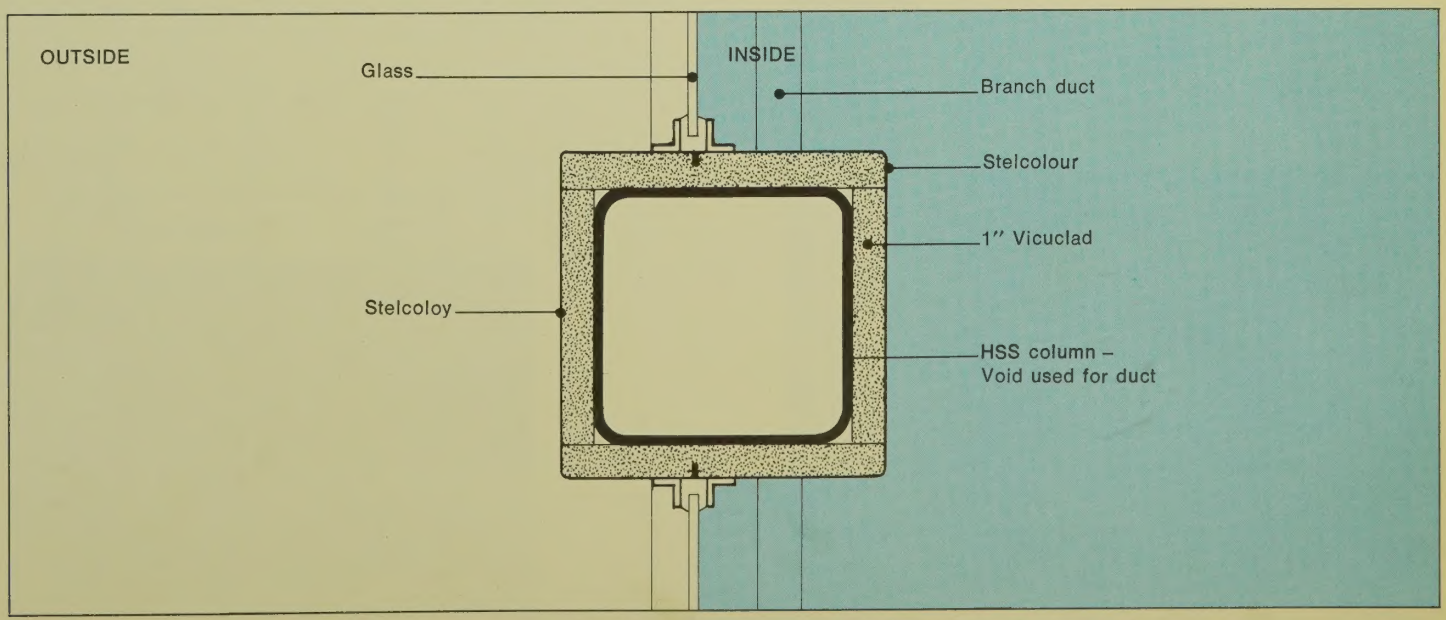


Figure 18 HSS columns at 10-foot centres and utilizing the void in the column as the duct supply.

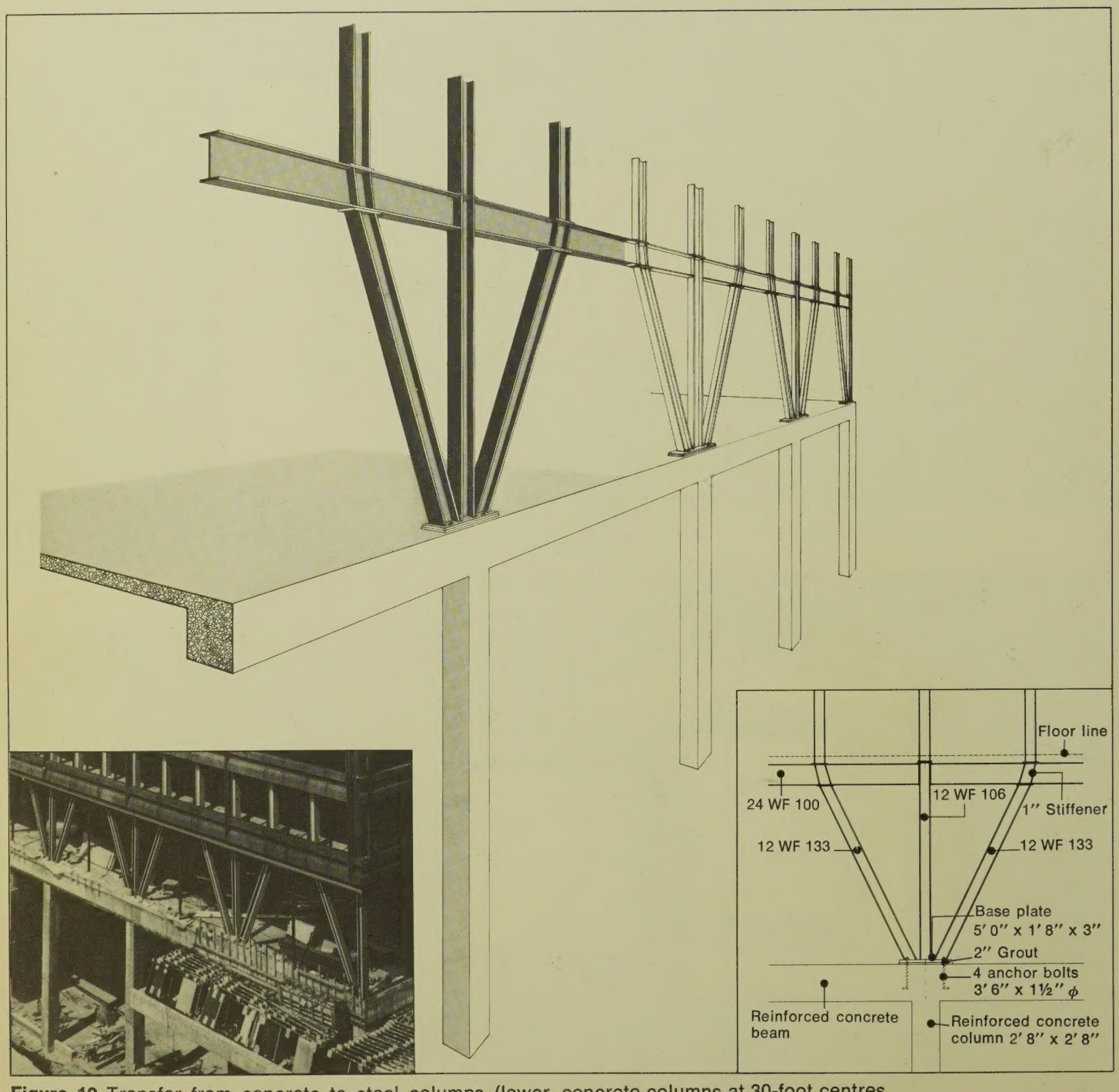


Figure 19 Transfer from concrete to steel columns (lower concrete columns at 30-foot centres, upper steel columns at 10-foot centres).

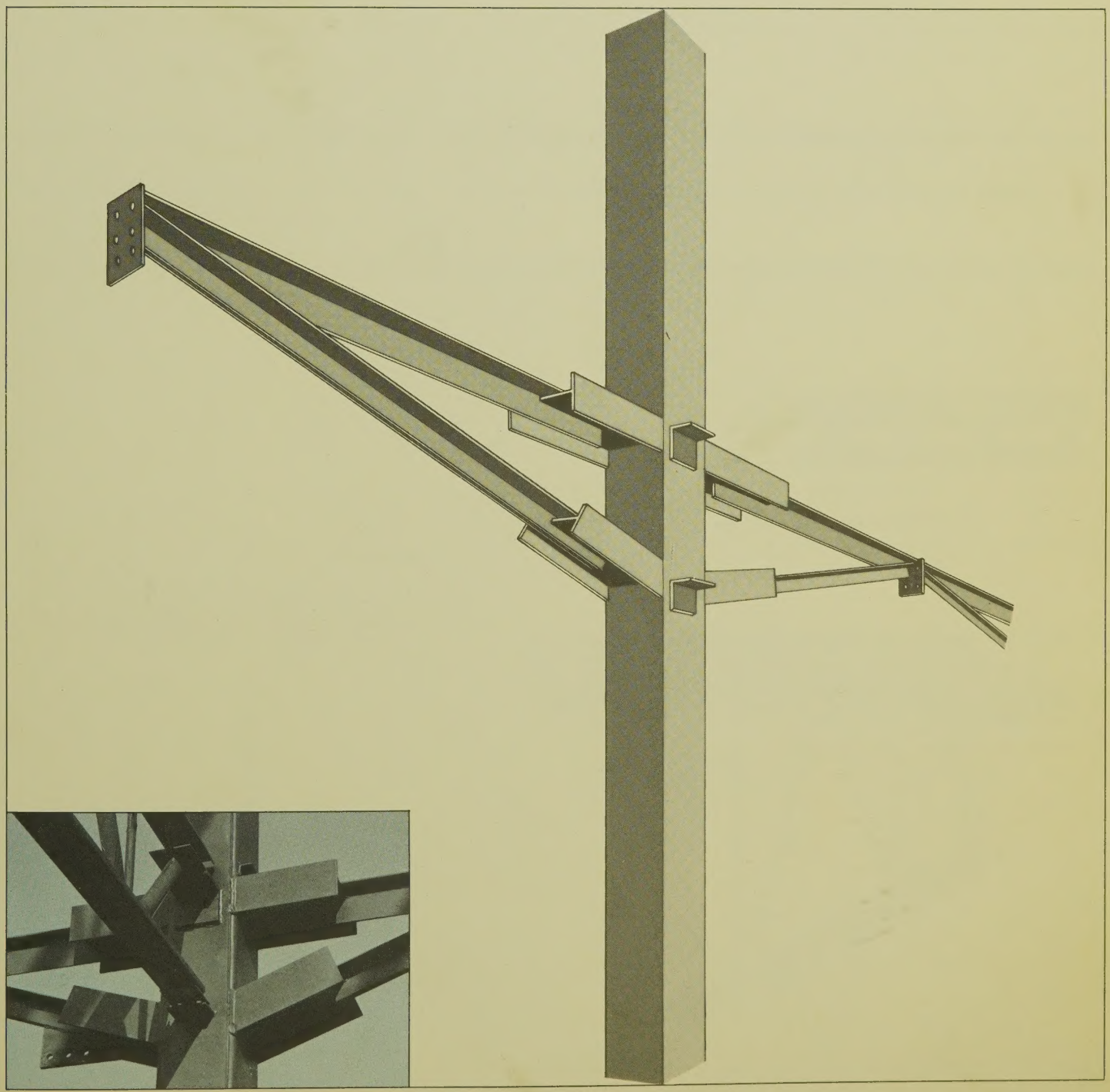


Figure 20 Prefabricated HSS column with spandrel ("tree" section).

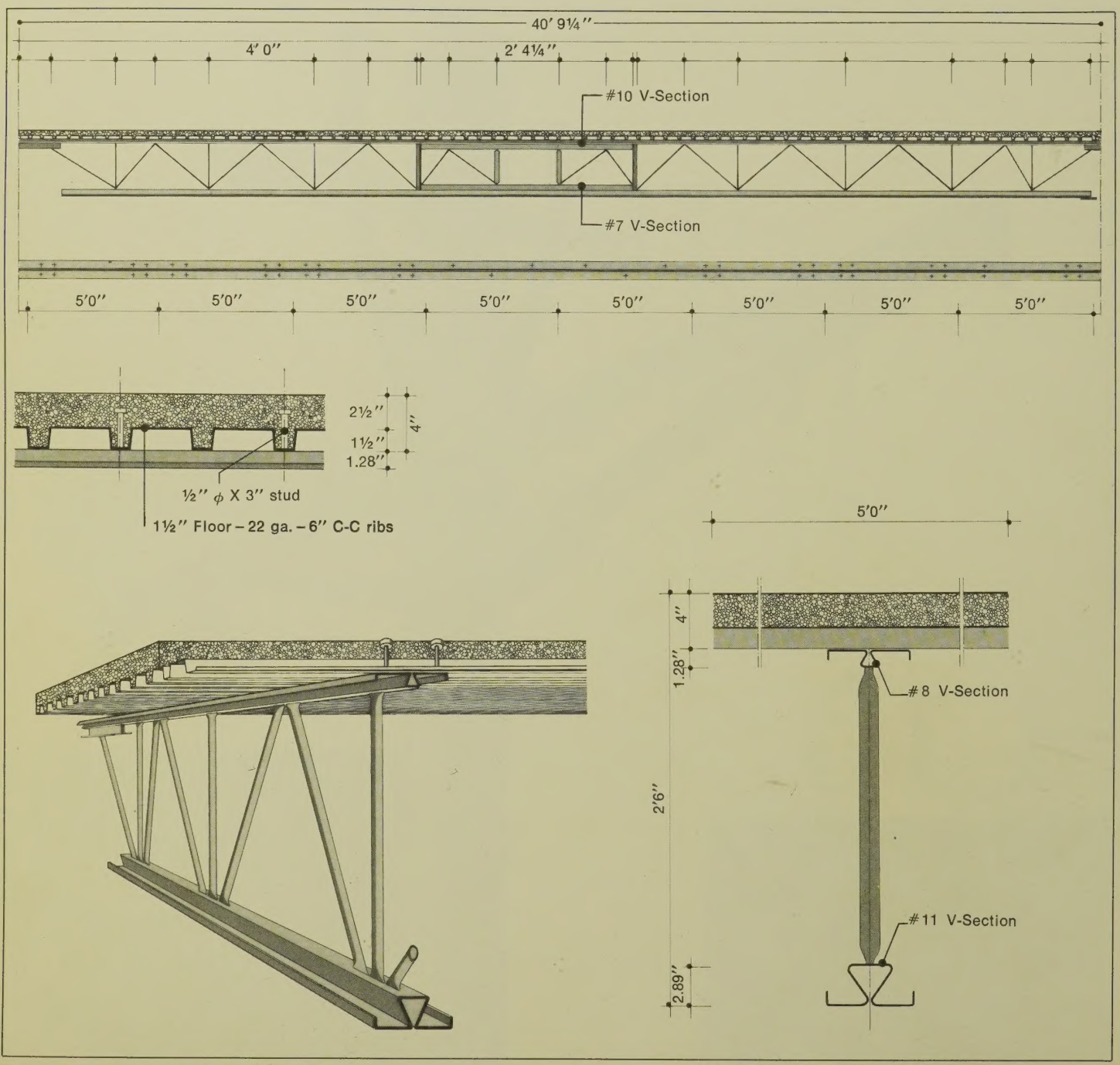


Figure 21 Composite open web steel joists as used on the Stelco Tower. Also a view of Stelco Tower floor. The 4-inch concrete slab consists of nominal 3000 psi concrete, ½-inch shear studs (3-inches long) welded through the steel floor to the top chord in pairs at locations as shown.

The floor was designed for a live load of 85 psf including partitions, 10 psf for ceiling and mechanical services and a dead load of 45 psf including joists, steel floor, concrete slab, etc. A section of each floor adjacent to the core was designed for 125 psf live load to provide for computer loads. The overall joist depth, including the concrete slab, measures 30 inches and the typical span is 40 feet. The individual members were cold formed by Great West Steel (Eastern) Limited from sheet steel having a minimum yield strength of 55 ksi after cold forming. The 0.153-inch thick chords are cold formed hat sections, while the webs are cold formed, open-seam tubes which are stitch-welded. A reinforced 2-foot 3-inch wide x 1-foot 6¾-inch high opening for air conditioning ducts is provided at mid-span (figure 21). The 1½-inch cellular steel floor, with cells at 6-inch centres, has three cells in every 5 feet which are closed for electrical and communication services. The cellular portion of the floor uses 20/18-gauge sheet steel (Stelco's Colourbond* wiped zinc coating) while the non cellular part is made from 22 gauge. The 4-inch (overall thickness) concrete slab consists of normal 3000 psi concrete. ½-inch diameter shear studs, 3 inches long, are welded through the steel floor to the top chord in pairs, at the locations shown in figure 21. The steel floor was supplied and erected by Lord & Cie Limitée.

Figure 22 shows the load deflection curve for the 40-foot span test joist. It can be seen from this curve that at a load of approximately 13 kips, the composite interaction between the steel and concrete begins to break down and the curve deviates from the initial straight line. The curve eventually levels out as the joist undergoes plastic deformation. The joist was loaded to failure and ultimate failure was due to web member buckling. Large deflections of the joist near failure, gave rise to high secondary stresses which eventually combined with the compressive axial load to cause web member buckling. The fact that the load deflection curve did level out prior to failure, indicated that the ultimate bending strength of the joist was realized prior to this web failure. Test results also showed that prior to collapse the bottom chord strain (figure 23) was well beyond the yield strain of the steel,

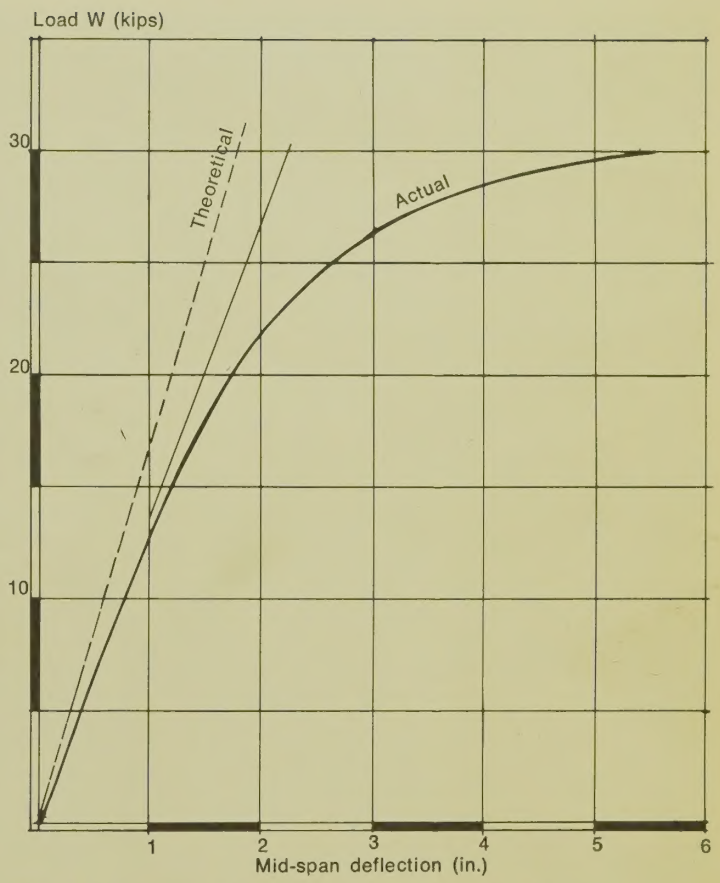


Figure 22 Stelco Tower joist load-deflection curve.

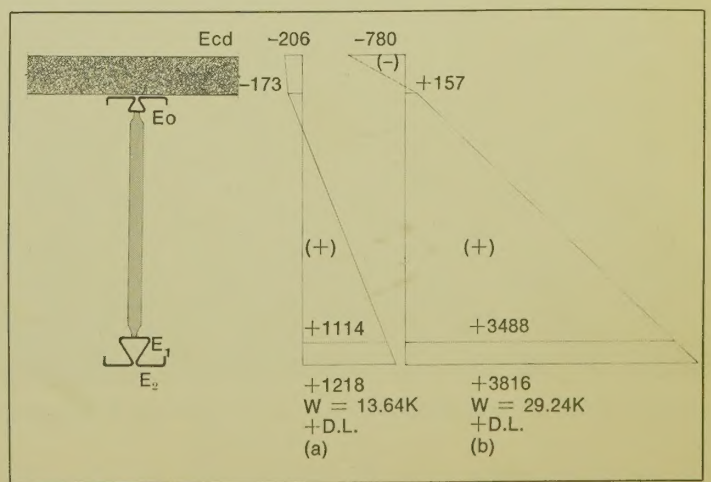


Figure 23 Stelco Tower joist strains (inches/inch x 10^{-6}).

*Registered trade name

Stelco Tower during construction: HSS columns, K-spandrels, joists and steel floor.

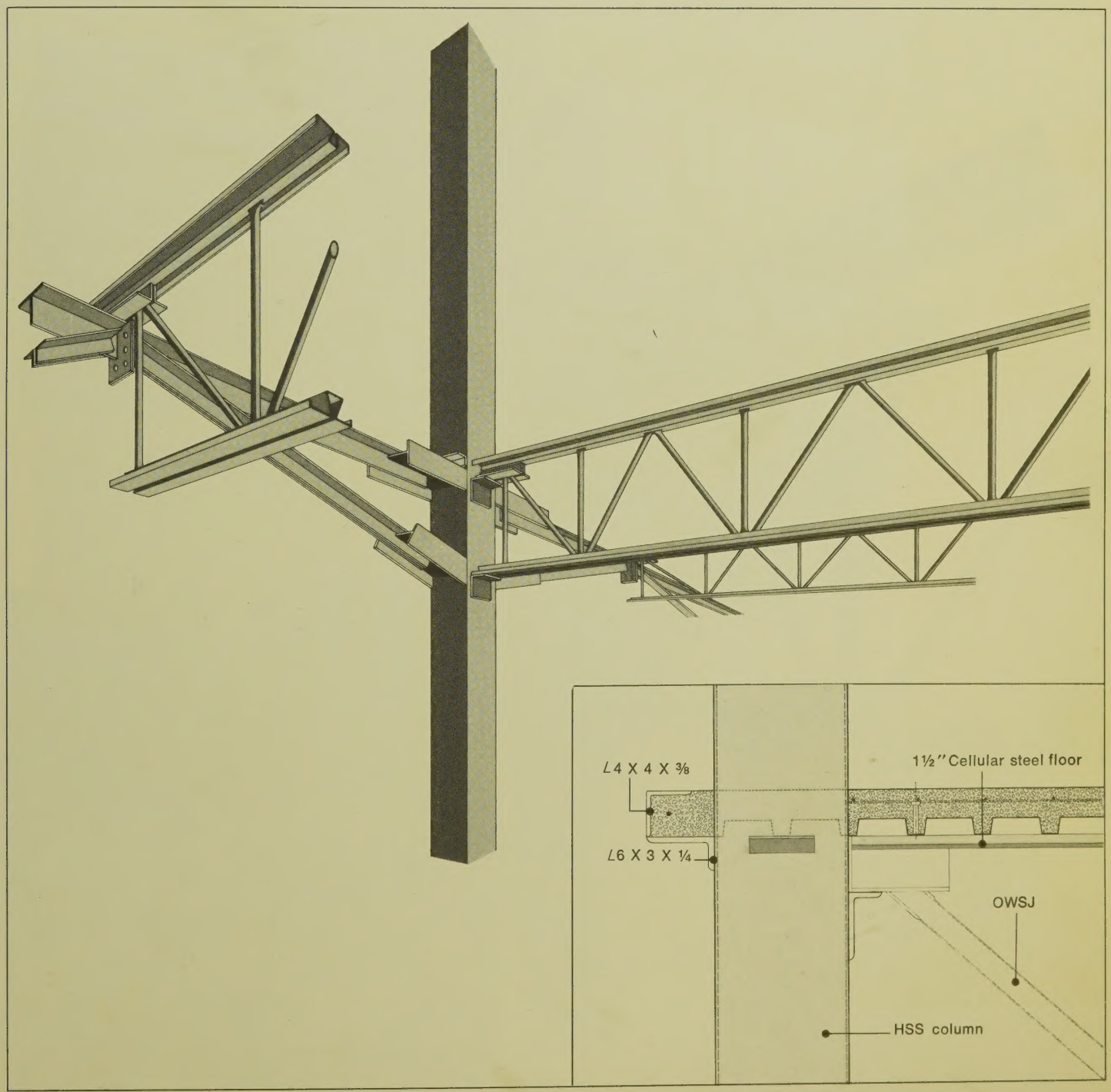


Figure 24 Joist to column and spandrel connection.

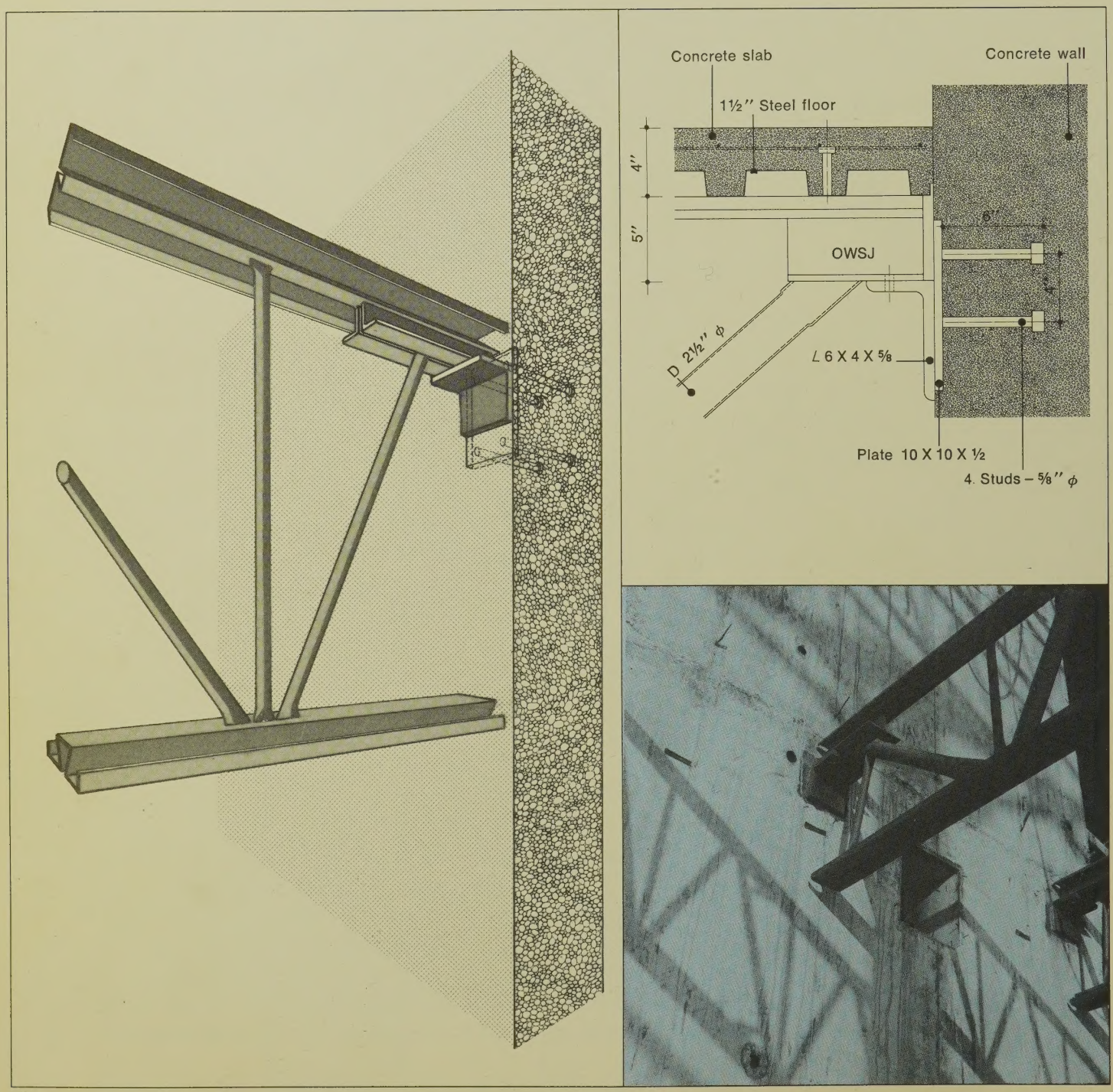


Figure 25 Joist to core connection.

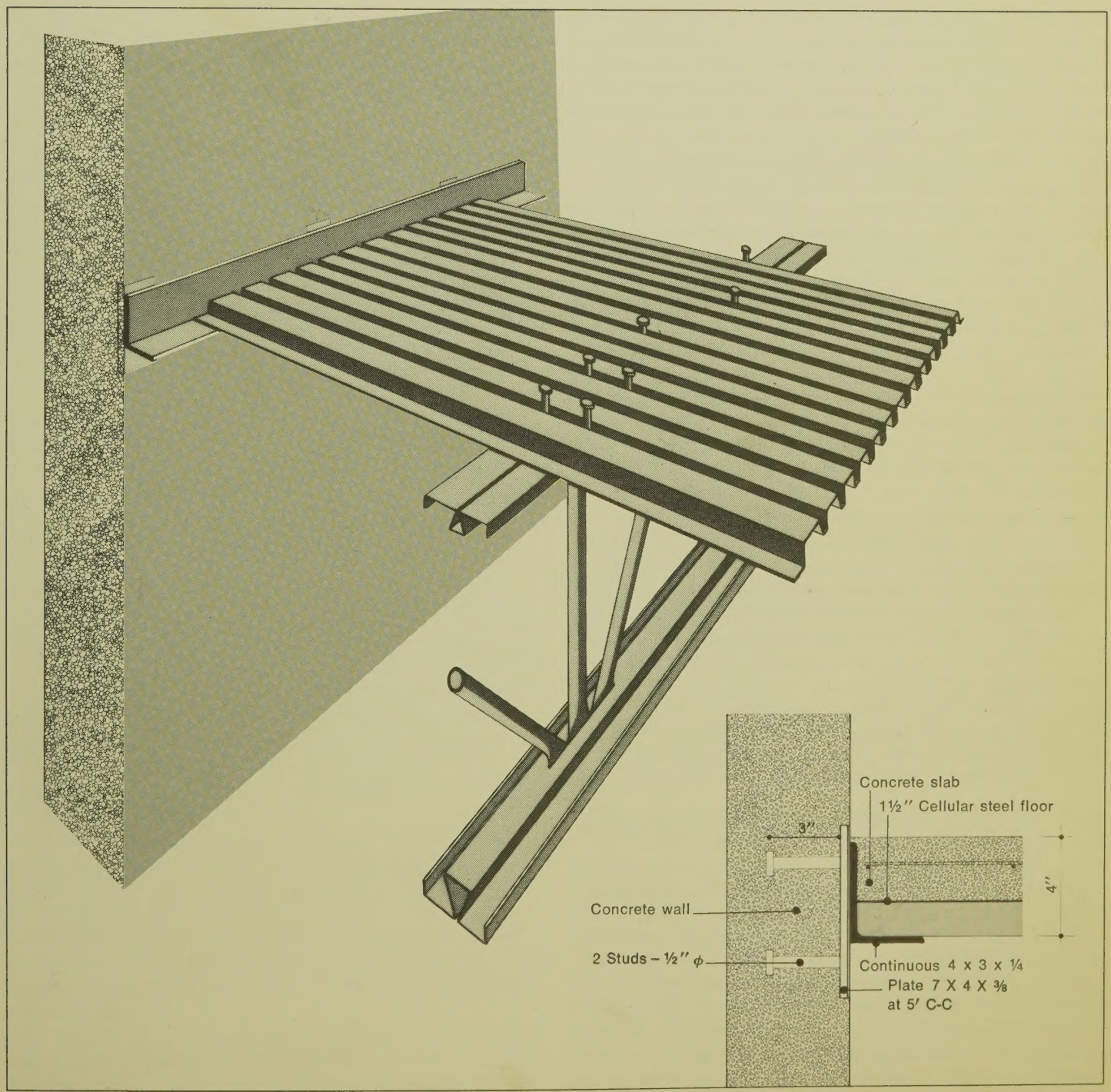


Figure 26 Floor to core connection.

indicating that the ultimate bending strength of the joist was achieved prior to failure. Stelco Technical Bulletin 11 "Design and testing composite open web steel joists" outlines in detail the ultimate strength design procedure for the composite open web steel joists used in the Tower.

Open web steel joists and cellular steel floors allow designers to provide economical designs for large open areas (with floor spans of 40 feet and greater). More efficient floor space utilization results from the elimination of interior columns. Other advantages include greater ease in placing or moving partitions, and flexibility in installing, enlarging or relocating HVAC as well as electrical and communications services.

Connections: Connection details for joist to column, joist to core and steel floor to core are illustrated in figures 24, 25 and 26 respectively. The joist to column connection utilizes angle seats for both top and bottom chords.

To facilitate the connection of the steel joists to the concrete core, steel plates were embedded into the concrete by ⅝-inch diameter steel studs during the pouring of the concrete core. At the time of steel erection, angle seats were field welded to these plates at the exact elevation. The rather large tolerances, which occur with reinforced concrete, were overcome in this way, thereby permitting the economical use of a combination of concrete and steel framing. The top chord of the joist sits on the angle seat. Similarly, as shown in figure 26, the same detail is used to connect the open ends of the cellular steel floor to the concrete core.

Costs and floor area: Based on a gross floor area of 392,986 square feet for 22 office and two mechanical floors, the structural steel, including floor joists, weighed 8.5 psf. The steel floor and shear studs weighed 2.4 psf, resulting in a total steel weight of 10.9 psf. The 1970 cost for the structural steel, joists and steel floor (with studs), based on the above gross floor area, was $2.90 per square foot. This is an economical cost in view of the fact that the Tower was designed for relatively high live loads: 85 psf including partitions in most areas and 125 psf in selected areas for computers.

4: Fire protection

An integral part of high-rise building design is the provision of adequate fire protection. We believe that the system chosen by the designers for the Stelco Tower is not only functional and effective, but also economical.

Fire protection requirements for this building were determined from the 1970 edition of the National Building Code of Canada. The building is classified as a Group D, Business and Personal Service Occupancy, consequently the columns and floor system were required to have a 2-hour fire endurance rating. The exterior wall system was not required to have a fire rating, because the limiting distance from the building to the centre line of the street was sufficient to permit 100 percent openings.

Floor-ceiling system: Two methods were considered for protecting the open web steel joist floor system: a fire rated ceiling and direct spraying of the joists.

In designing the HVAC system, the mechanical engineers decided that the ceiling plenum would be used for the return air. Slots located in the sheet steel frame of the lighting fixtures would act as exhaust points.

In evaluating the various fire rated ceilings available, it was found that each one had some limitations relative to its use in this particular building. A gypsum board ceiling did not allow the flexibility desired for relocation of lighting fixtures. Existing ceiling tile systems did not incorporate ventilating type lighting fixtures and a coffered ceiling was not acceptable, due to space limitations. Because of these considerations, direct spraying was selected as the fire protection method for the floor joist system.

Both cementitious and asbestos free mineral fibre sprays were specified as alternates in the tender documents. Donalco Services Limited were the successful tenderer with the cementitious spray. Thicknesses used were: 1½-inches applied directly to the joists without the use of lath, ½-inch applied to the underside of the cellular steel floor, and 1½-inches to the beams and column caps.

The results of an Underwriters' Laboratories Incorporated test by the Vermiculite Institute, Design No. G701 formed the basis for acceptance of the Stelco Tower joist system. This tested assembly was a composite joist consisting of a concrete slab having an average thickness of 3 inches on corrugated steel form units supported by 9½-inch deep joists. The assembly was protected with 1½-inches of cementitious spray, applied directly to the exposed surfaces of the joists, and ½-inch applied to the corrugated steel form units. This system gave a 3-hour restrained assembly rating and a 2-hour unrestrained assembly rating.

Since the webs of the joists in the above test assembly were heavier than some of those specified in the Stelco Tower design, the results of this test could not be applied directly. It was necessary to apply a scaling formula to determine the thickness of spray which would provide the required 2-hour fire protection. Also, the thickness of one of the webs was increased to provide increased fire endurance. A complete description of the calculations is given in the paper "The Design and Economics of Composite Open Web Steel Joists" by A. H. Atkinson and J. A. Cran delivered to the 1972 Canadian Structural Engineering Conference in Montreal. From these calculations it was determined that 1½-inches of cementitious spray would be required to give the necessary 2-hour fire rating.

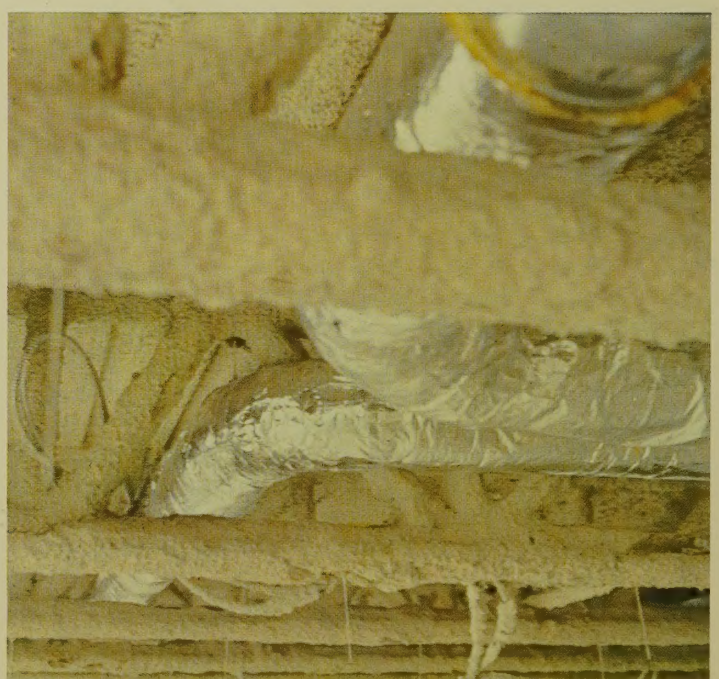
Another test on a joist protected by direct spraying has also been listed by Underwriters' Laboratories of Canada. This test is listed as Design No. 0803 and gives an unrestrained beam rating of 2 hours for a joist protected with sprayed fibre.

Analytical methods for determining fire endurance are gaining more acceptance and research is currently being done in several areas. Mr. W. W. Stanzak, the steel industry's fire fellow at the National Research Council of Canada, and Underwriters' Laboratories Inc. are researching analytical methods for determining the fire endurance of columns.

Columns: In the preliminary design of the building, fire protection of the columns by water filling was considered. However, due to the close spacing of the columns (10-foot centres), it was felt that the large amount of piping required for water circulation, in the event of fire, would make the system too costly.

In the final design of the Stelco Tower, four methods were considered to protect the columns: a vermiculite board fastened directly to the column by an adhesive, a direct spray of the column with a sheet steel cover

Installation of the sheet steel column covers.



Application of spray fire protection.

for architectural finish, gypsum wallboard, and a sheet steel-gypsum wallboard laminate column cover.

The vermiculite board and the direct spray with a sheet steel cover were found to be too expensive. The sheet steel-wallboard column covers and the gypsum wallboard method were found to be competitive in cost. However, the architect felt that sheet steel offered a more durable finish, therefore, the sheet steel-wallboard column covers were chosen.

These column covers were developed and supplied by Stanley-Taymouth Ltd. They comprise two layers of 5/8-inch gypsum wallboard laminated to 22-gauge (.0299 inches) sheet steel. The column covers are shop fabricated and come to the field in two pieces. These pieces are fastened together in the field by means of a snap connector and pop rivets (figure 27). Angles fastened to the concrete floor slab hold the column covers in place at the bottom, and brackets butting against the column hold the column covers in place at the top.

Both prefinished and post-painted sheet steel was used. The post-painted column covers have a wiped coat galvanized finish for corrosion resistance prior to painting. The prefinished steel covers utilized a plastisol coating. It provides a very durable, thick coating which does not show scratches and which has good resistance to marring.

Costs: The tender prices for the fire protection were: $0.51 per square foot for the floor system plus $0.14 per square foot for the sheet steel column covers for a total of $0.65 per square foot for the Stelco Tower fire protection. This price is based on a gross floor area of 392,986 square feet for 22 office floors and two mechanical floors. The above costs represent 1970 levels.

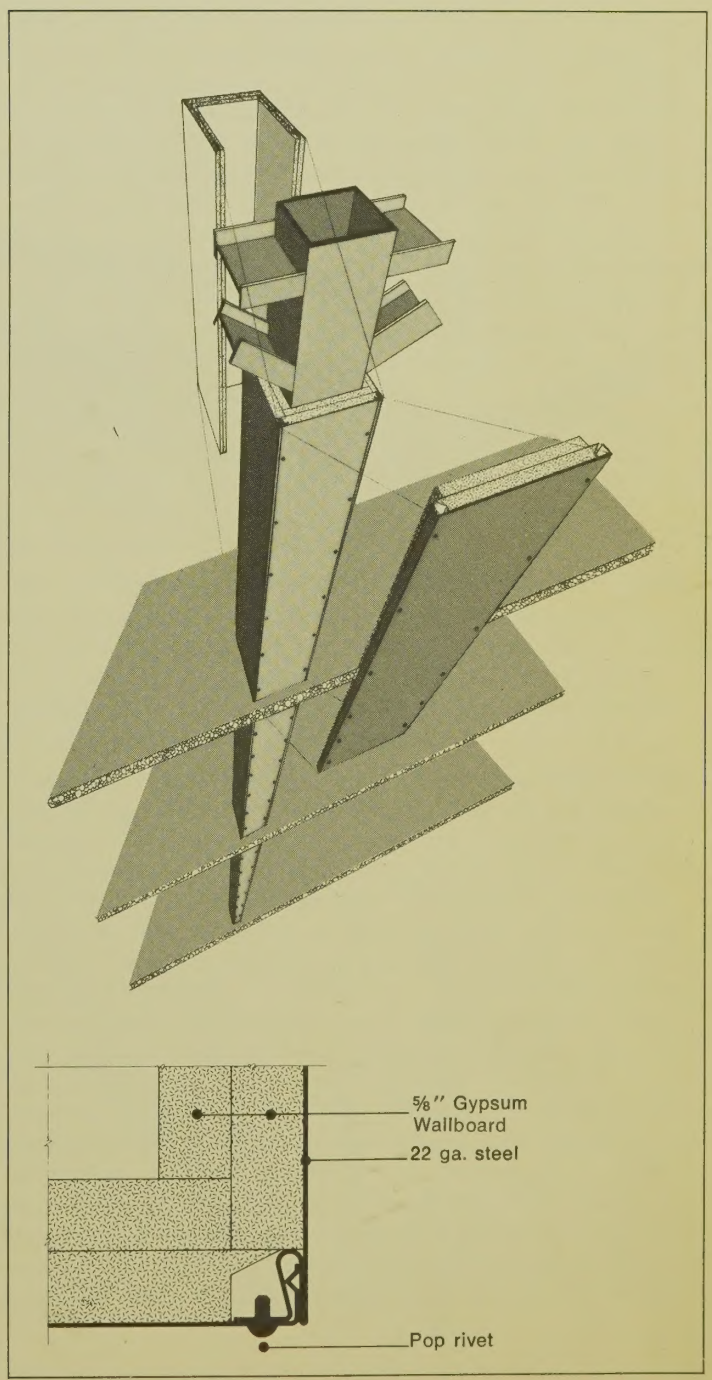


Figure 27 Fire protection of the HSS columns utilizing sheet steel – gypsum wallboard laminate column covers.

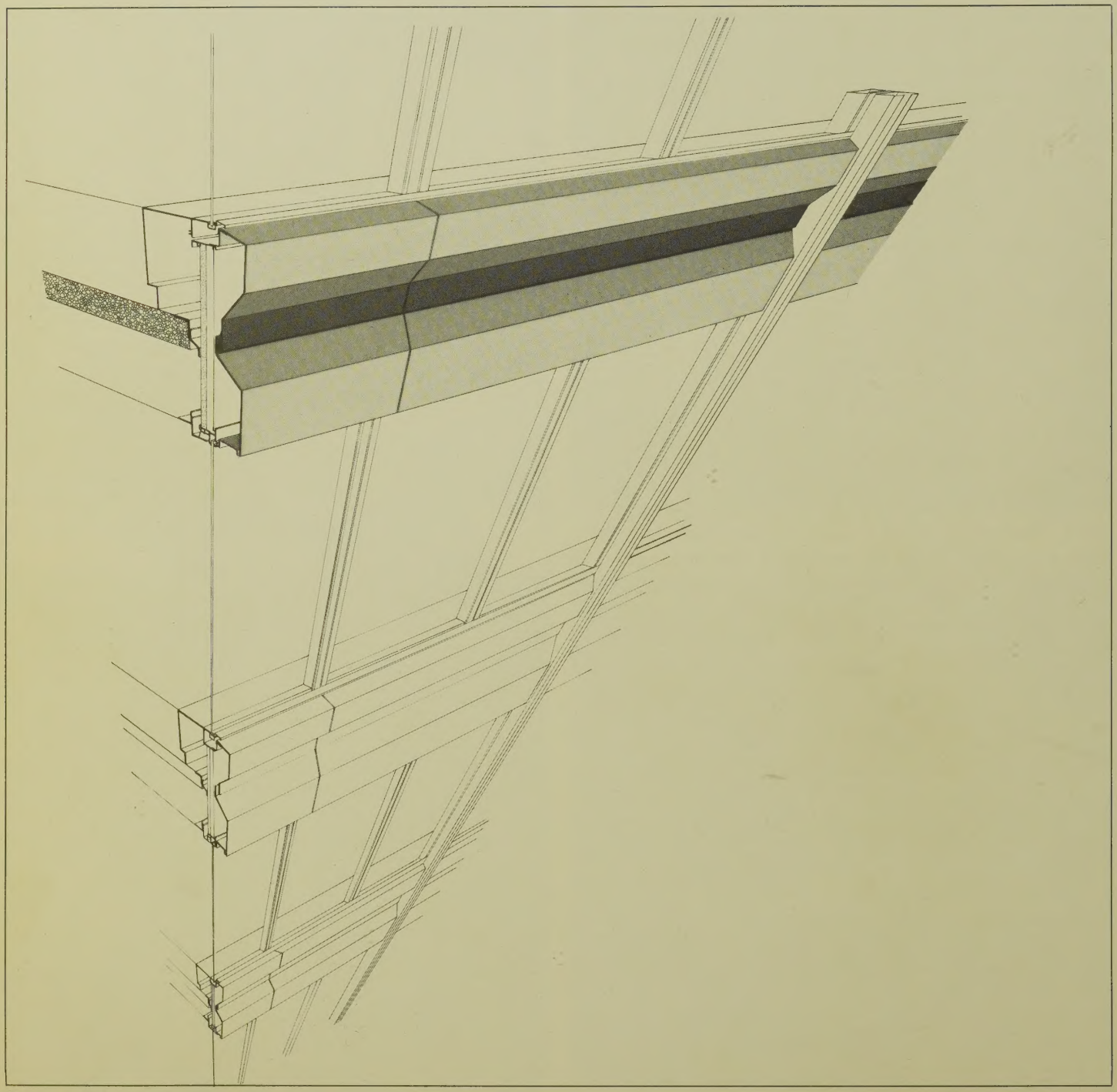


Figure 28 Stelcoloy weathering steel curtain-wall.

5: Exterior wall cladding

One of the main objectives of the Stelco Tower architect was to develop an exterior curtain wall that was not only functional and aesthetically pleasing, but also economical. In order to ensure that all these conditions were met, a comprehensive study was carried out on the various types of wall systems available.

Effect of structure: One of the first design decisions made by the consulting engineers concerned the curtain-wall. Should it act as an integral part of the structural frame and thus be incorporated into the structure to withstand, and accommodate, all movements imposed by such forces as expansion and contraction, earthquakes and wind pressures? Or should it be designed simply as a "thin skin" wall to resist wind loads, take care of expansion and contraction, and keep the weather out?

Under the first alternative, the exterior wall would provide a shear diaphragm to work in conjunction with the periphery columns to form a "tube" which would withstand lateral forces. This system is economical for buildings in the 45 to 125-storey range. For buildings with fewer stories, a portal frame design or a combination of a steel frame and concrete core, has proved less costly.

When the height of the Stelco Tower was finalized at 350 feet, it was concluded that the most economical lateral bracing system would be a combination of concrete core and steel frame (chapter 3). This having been determined, it followed that the exterior wall would only be required to withstand external loads due to positive and negative wind pressures.

Effect of HVAC system: Another area which influences the cost of the exterior wall cladding is the HVAC system. When using an induction system, one of two methods of supplying the primary air can be chosen: 1. A vertical riser system where the primary air ducts are located along the periphery columns. 2. A horizontal system where the ducts are located in the ceiling plenum and are fed by risers located in the central core.

In a structural steel floor system where there are beam, joist or spandrel to column connections on the three interior faces of the exterior columns, the location of a vertical duct is generally restricted to the outside face. Depending upon the size of the duct, it is quite possible that the entire column assembly would protrude beyond the plane of the wall (figure 14). This would necessitate jogs or breaks in the curtain-wall system which has the effect of increasing costs.

However, with a horizontal HVAC system, column assemblies are considerably smaller and a continuous membrane curtain-wall can be chosen (figure 15). As indicated in chapter 3, the horizontal riser system was adopted after evaluating the various schemes available.

Aesthetics, economics and performance: Having decided on the basic configuration of the exterior wall, the next step was to determine the most suitable cladding materials, keeping in mind aesthetics as well as performance and costs.

In considering aesthetics, the architect wanted to use a material which not only blended in well with the surrounding area but also depicted Hamilton's "Steel City" image. The use of steel was considered most appropriate, but a number of problem areas had to be resolved prior to its final selection.

Cost was of primary concern. Past history had shown that there had been very few all steel curtain walls designed for high rise office towers. Those walls that had been used were in a price range above this project's budget. There was also the problem of maintenance. The architect dictated that the wall system should be as maintenance-free as possible. To satisfy the requirements of aesthetics and low maintenance, the architect chose Stelcoloy* weathering steel for the exterior face of the curtain wall system. Stelcoloy is a weathering steel which through time forms its own protective coating and consequently requires no maintenance. This coating is formed by repeated cycles of wetting and drying which form a protective oxide that seals off the steel from the atmosphere. Stelcoloy undergoes a colour transformation while forming this protective coating. Commencing with blast cleaned or pickled steel, it rapidly transforms to a bright orange,

*Registered trade name – Reference: Stelco Technical Bulletin 10, Designing with Stelcoloy weathering steel.

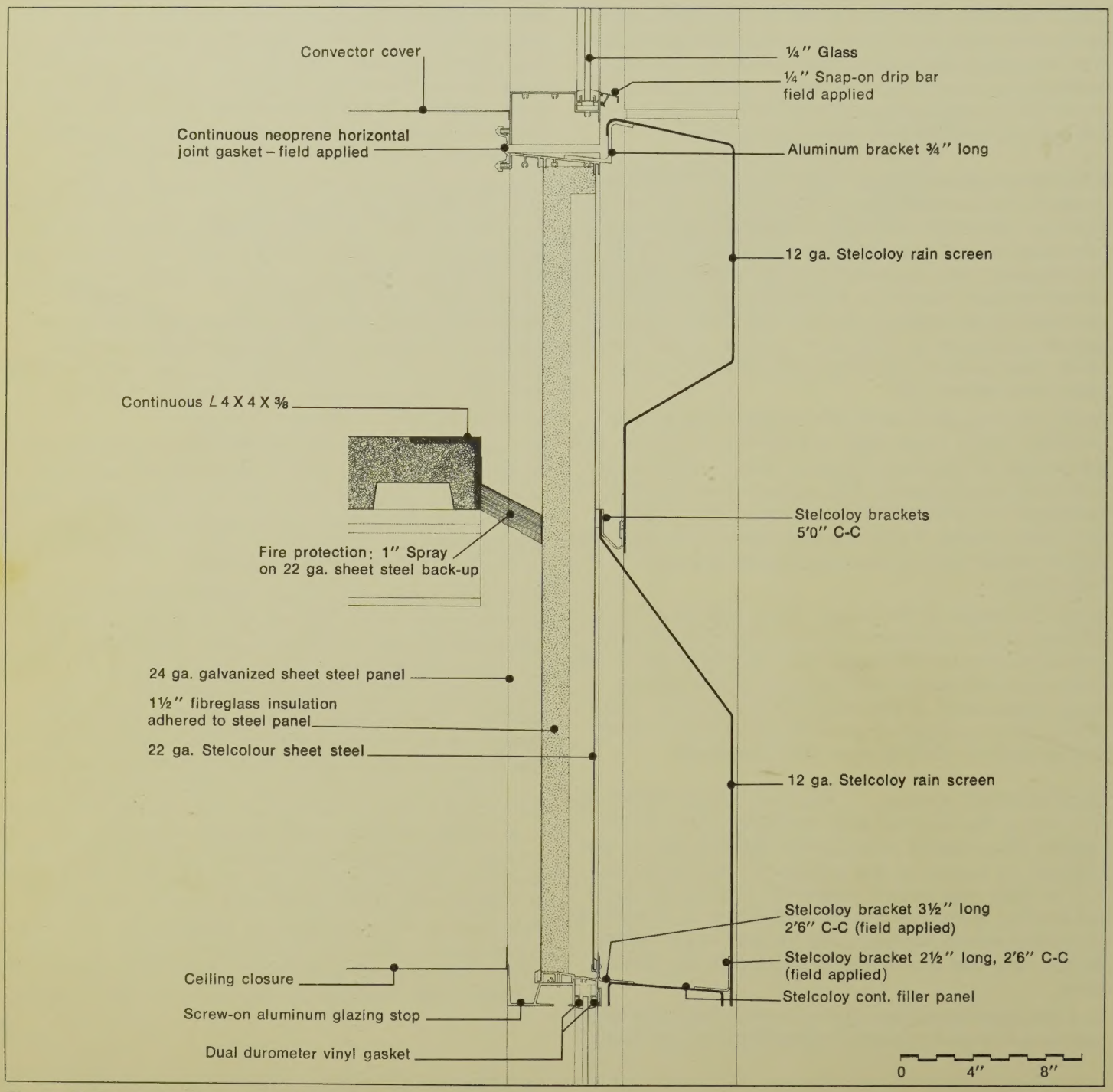


Figure 29 Cross-section of Stelcoloy weathering steel curtain-wall.

then proceeds to a light brown, next to a dark brown, and finally, a dark patina. The protective coating provides protection against the elements, remains maintenance-free and satisfies aesthetic requirements. Having solved the initial two goals of maintenance-savings and aesthetics, the task then remained to design the balance of the wall system to meet other specified performance criteria, still keeping in mind relative economics. The cost problem was resolved by Canadian Pittsburgh Industries who fabricated and erected the curtain-wall. The solution lies in the adaptation of the standard rain screen principle wherein the curtain-wall system consists of two distinct elements: an outer wall which acts as a barrier against driving rain and an inner wall which controls moisture, light and solar penetration as well as temperature transmission. Between these two walls is a well-vented airspace in which the pressure is equalized to that of the exterior, thus discouraging moisture penetration. Any moisture or condensation which may form, is discharged through spaces provided at the base of each panel.

Outer wall: The outer "rain screen" wall consists of horizontal spandrel panels of 12-gauge (0.1046-inch) hot rolled Stelcoloy sheet (figures 28 and 29). These panels are either connected directly to the mullions of the interior wall, or are supported by aluminum brackets framing into the horizontal sills of the interior wall frame. Electrolytic separation between aluminum and steel is accomplished through the use of a zinc chromate coating. Horizontal surfaces on the inside face of the wall are also coated to prevent corrosion.

One feature of this exterior wall is the elimination of close tolerance requirements for both material and fitting. Gaps do not require caulking, consequently fabrication and installation costs are kept to a minimum.

One aspect of Stelcoloy weathering steel which must be considered at the design stage is the runoff of soluble products during the initial weathering period. This runoff can stain adjoining porous materials if provision is not made to protect these areas. In the case of the Stelco Tower, permanent gutters are located around the entire periphery of the building below the louvres located at the lower mechanical floor. These gutters catch any runoff from the wall above.

With respect to glazing, runoff from the Stelcoloy will not have any detrimental effect on the surface of glass if frequent window washing is performed. Provision was made to clean the windows on a more frequent basis (every three months for the first two years), until the initial stages of heavy runoff are concluded. As part of the exterior wall, vertical guides for the window washing equipment are located at 30-foot centres around the periphery of the building. These guides are also fabricated from 0.1046-inch Stelcoloy weathering steel (figure 30).

Inner wall: Insulated panels consisting of 2 skins, plus insulation, are commonly found on low-rise structures because they are both functional and economical. The architect chose a similar system for the interior wall of the Stelco Tower consisting of prefinished Stelcolour* sheet steel, fibreglass insulation, single glazed ¼-inch Solar Bronze heat-absorbing glass and Statuary Bronze Hardcoat aluminum extruded sections. Extruded sections were used, because they proved the most economical way of accommodating the glazing, expansion joints and moisture seal details (figures 28 and 29). The insulated panels consist of 22-gauge (0.0336-inch) prefinished Stelcolour sheets on the exterior face, followed by a 1-inch air gap, and 1½ inches of fibreglass insulation bonded to a 24-gauge (0.0276-inch) Colourbond wiped, zinc-coated sheet steel panel. The interior sheets act as the vapour barrier for this system.

Each interior wall panel, which is 12 feet high by 5 feet wide, was fabricated in the shop and shipped to the site ready for installation.

*Registered trade name.

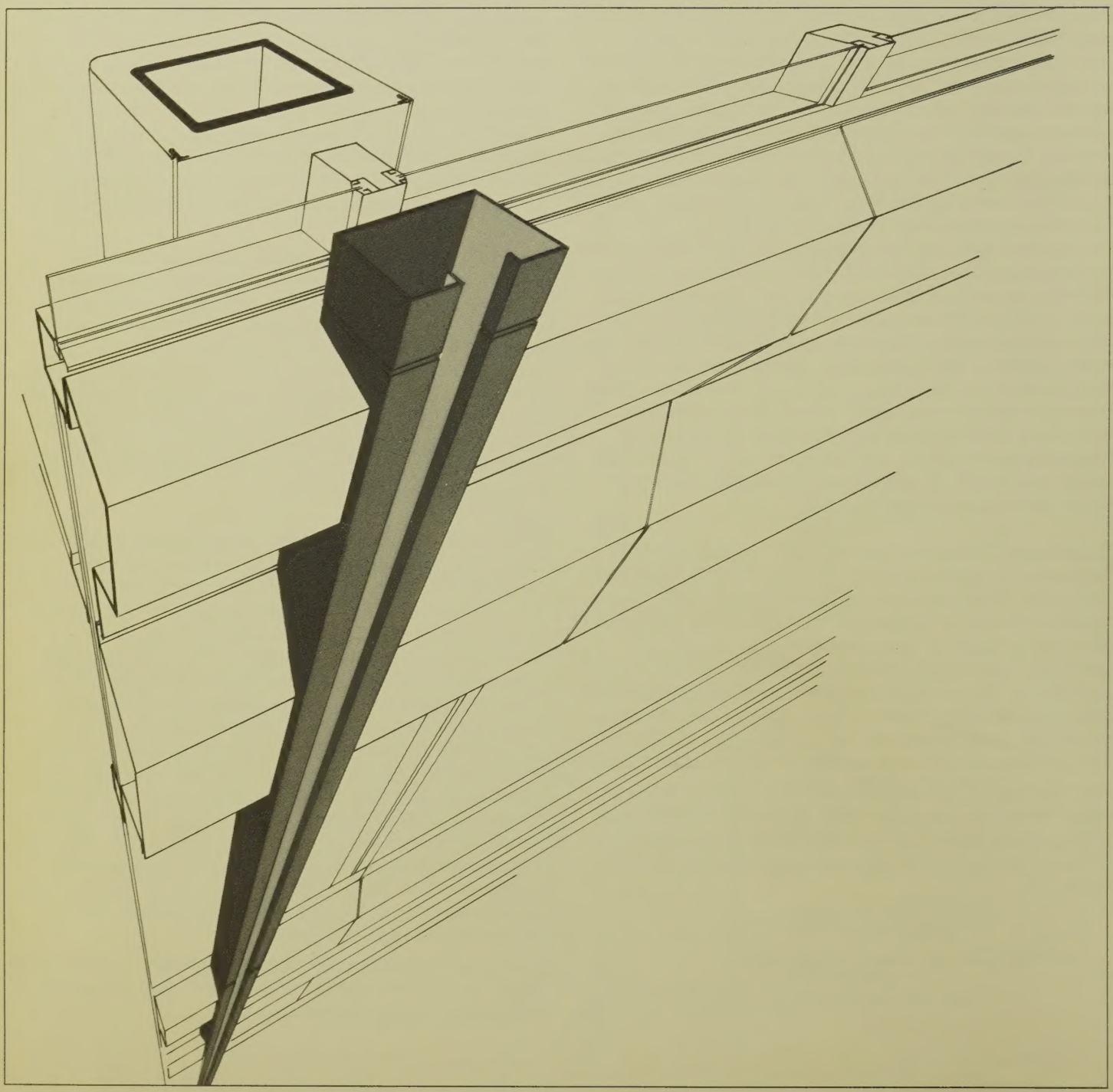


Figure 30 Vertical guide for window washing equipment.

Installation: The installation sequence of the curtain-wall commenced in the field with the interior wall panels placed from inside the building, and anchored to the main structure by means of structural brackets attached and welded to inserts in the concrete floor slab (the vertical frame of the prefabricated panels is designed to act as the mullion). Slotted holes in the supporting brackets allow movement in three directions, to accommodate both expansion and contraction due to temperature changes. The Stelcoloy spandrel panels were then attached to the frame of the interior wall. Finally the single ¼-inch glazing was installed, utilizing a dual durometer vinyl spline for a seal between the glass and frame.

Costs: This curtain wall design has proved to be most successful. Not only has it satisfied all performance and aesthetic criteria laid down by the architect but has also proven to be economical. Based on a total wall area of 142,000 square feet, this cladding was supplied and installed for a unit price of $7.35 per square foot. The cladding for the two mechanical floors, consisting of Stelcoloy panels entirely, was supplied and installed for a unit price of $5.50 per square foot, based on a total wall area of 25,000 square feet. All costs are at 1970 levels.

6: Stelco Tower

Construction data at a glance

Height: a 350-foot, 26-storey office building including 22 typical office floors and two mechanical floors.

Floor area: the total gross floor area of the Stelco Tower is 392,986 square feet (including the upper and lower mechanical floors). Each office floor covers 16,599 square feet with floor plan dimensions: 105 by 150 feet and a 5-foot module is adopted to aid standardization of office layout. For the upper floors non-rentable floor area represents only 6 percent of gross floor area, while for the lower floors it amounts to 9.2 percent of gross.

Wall area: 167,000 square feet of which 25,000 square feet represent the wall area surrounding the two mechanical floors.

Concrete core: stands independently and does not require support from the structural steel frame.

Perimeter columns: 10 feet on centres 50,000 psi minimum yield strength HSS – 12 x 12 x .450-inch on the 8th floor to HSS – 6 x 6 x .250-inch HSS on the top floor.

Floor system: composite open web joists used in combination with a 1½-inch cellular steel floor and concrete slab.

Fire protection: open web steel joists protected by 1½-inches of cementitious spray; ½-inch of cementitious spray applied to the underside of the cellular steel floor providing a 2-hour fire resistance rating. Columns have sheet steel-wallboard covers.

Exterior wall cladding: Stelcoloy weathering steel.

Costs (1970):
Curtain-wall $7.35 per square foot
Fire protection $0.65 per square foot
Structural steel (10.9 psf total steel weight) $2.90 per square foot.

7: Conclusions

This book tells the story of the new 26-storey, 392,986 square-foot Stelco Tower completed in early 1973. Although Stelco is the prime tenant, the company does not own the building. All steel concepts adopted had to be competitive with other methods before being accepted by the developer. The closing paragraph of chapters 3, 4 and 5 describe the low costs attainable with modern construction steel techniques. Proving steel's superior quality and economy as a structural and architectural material, here are the Stelco Tower's main features:

1. A structure, comprising a concrete core, periphery columns from HSS (hollow structural sections) and composite open web steel joists.

2. Long spans and the absence of interior columns offer maximum floor space as well as flexibility in office arrangements.

3. An attractive Stelcoloy weathering steel curtain-wall which requires no painting or subsequent maintenance.

4. An architecturally distinctive structure in the centre of Hamilton, providing the community with a major source of pride.

Owners and developers: Greater Hamilton Developers Limited (formed by Yale Properties Limited and The Standard Life Assurance Company)

Architect: Arthur C. F. Lau and Associates

Structural engineers: G. Horvath and Associates

Mechanical and electrical engineers: Keith Associates Limited

The Steel Company of Canada, Limited
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Toronto, Ontario

General Offices:
Hamilton, Montreal, Edmonton

Sales Offices:
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Toronto, Hamilton, Windsor, Winnipeg,
Regina, Edmonton, Calgary, Vancouver:
J. C. Pratt & Co. Limited, St. John's; and
representatives in principal world markets.

This Stelco Tower design story was prepared by Stelco's Sales Engineering Department. Providing design assistance and technical data, Stelco's sales engineers work directly with architects, engineers, and all customers who are concerned with material selection and application. Backing them up are product metallurgists with their specialized knowledge of steel's chemical and mechanical properties. For assistance and further information on the design aspects and products described in the Stelco Tower design story please contact Stelco's Sales Engineering Department through any Stelco Sales office.

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